ANALYSING DYNAMICS OF BIOFUEL PRODUCTION AMONG SMALLHOLDER FARMERS IN LAIKIPIA EAST SUB-COUNTY, LAIKIPIA, KENYA

BY

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DECLARATION

The project is my original work and has not been presented for a degree in any other university.

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The project has been submitted for examination with my approval as the university supervisor.

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Dr. T. Thenya

Date 22nd November 2021

DEDICATION

I would like to dedicate my project work to Mwema, my Husband for the unwavering support and encouragement to see me through. Special appreciation goes to my Children Lynda, Rhoda and Mike who endured my absence to ensure that I succeed in my endeavor.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CETRAD	Center for Training and Integrated Research in ASAL Development
CNO	Croton Nut Oil
EFK	Ecofix Kenya
FAO	Food and Agriculture Organization
GHG	Greenhouse Gases
GIZ	Gesellschaft für Technische Zusammenarbeit
IIASA	International Institute for Applied Systems Analysis
IEA	International Energy Agency
KNBS	Kenya National Bureau of Statistics
MOA	Ministry of Agriculture
NEMA	National Environment Management Authority
NGOs	Nongovernmental Organizations
SPSS	Statistical Package for Social Sciences
UN	United Nations

ABSTRACT

Biofuels have globally become important in the recent past due to the fact that countries are struggling to deal with the challenges of the increasing prices of fossil fuels and global warming. The demand for energy increases with growth in economic development as well as world's population increase. The goal of this research was to assess the dynamics of biofuel production among smallholder farmers in Laikipia East sub County in Laikipia County. The specific purposes of the research were to establish the different species used in biofuel production among smallholder farmers in Laikipia East sub-County Laikipia, to assess the drivers of biofuel adoption among smallholder farmers in Laikipia East sub-County Laikipia County and to evaluate the socio-economic impacts of biofuel production among smallholder farmers in Laikipia East sub County Laikipia. This study adopted a descriptive survey research design. The research targeted the 3000 small holder farmers who work with Ecofix Kenya and used a sample of 97 respondents. Systematic sampling was adopted in picking the farmers in the study. The study also targeted the 12 employees of EFK. All the 12 employees of EFK Group Laikipia and 4 Government officers were selected for key informant interview. The data was collected using questionnaires, interviews and focused group discussions. Quantitative data was analyzed and presented using expressive figures like frequencies, and proportions. Further Analysis of variance (ANOVA) was used to examine the hypothesis. Data generated interviews was examined using thematic approach. The research findings indicated that *Croton megalocarpus* is the common biofuel crop species grown in Laikipia East sub-County Laikipia and largely grown as a boundary species. The reasons for biofuel adoption among smallholder farmers in Laikipia East sub-County Laikipia are; to get wood (68%), additional revenue, decent shade for the farmhouse (78%), and access to markets (58%), exposure in the domiciliary and for fence resolutions (72%). Environment upkeep was a main motivation of biofuel yield agrobusiness among smallholder farmers in Laikipia East sub-County Laikipia (56%). Marketplace mandate (36.3%) land availability (42.9%) and policies (16.5%) were not key drivers for biofuel farming amid smallholder farmers in Laikipia East sub-County Laikipia. Biofuel production had a statistically significant socio-economic impact among smallholder farmers in Laikipia East Sub-County, Laikipia County ($p=0.000$).

The research endorses that Ecofix Kenya Company should contemplate offering/giving values to the farmers to inspire more production of the biofuel harvest, which will as well ensure that the business has a satisfactory foundation. The administration needs to endorse croton feedstock growing for ecological conservation, liveliness and decreased poverty amongst families.

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

The world’s inhabitants are predicted to attain 8 billion by 2025 (World Health Organization, 2018), with developing countries accounting for the majority of this rise (Lal, 2015). Around a third of the biosphere's people continue to rely on non-profitable energy bases to encounter their vigor stresses (World Health Organization, 2018). This category includes historically used oils like wood, agricultural wastes, and cow dung. According to estimates, 1.4 billion persons, or greater than 20% of the world's inhabitants, lack the capability to use electrical energy and consequently rely on biomass, while 2.7 billion persons, or over 40% of the world's inhabitants, cook with outdated biomass (IEA, 2011). The expanding volume of scientific evidence proving the critical nature of climate change mitigation has altered global and national attitudes on these issues (Gibbons, 2014).

Biofuels are carbon-based main and/or subordinate oils resulting from biomass that can be burned or converted into thermal energy via other means. They comprise both energy crops grown expressly for energy generation and multipurpose plantations and byproducts (residues and trash) (FAO, 2011). Plants, as well as agricultural, commercial, residential, and/or industrial waste, can be used to make biofuel. Carbon fixation in the modern era, such as that occurring in plants and microalgae via photosynthesis, is frequently employed in biofuels. Corn, palm oil, sugarcane, cottonseed, wheat, sunflowers, and soybeans are just a handful of the most often cultivated biofuel crops.

Governments and policymakers around the world were grappling with three major issues by the conclusion of the twentieth period: energy security concerns, a desire for economic

growth in both industrialized and unindustrialized states, plus the formation or maintenance of agricultural works, and the necessity to alleviate climate alteration and attain lesser greenhouse gas releases (Lang & Barling, 2012). Some biofuels species characteristics include quick growth, large yields, cheap water and maintenance costs, ease of coppicing, and the capacity to thrive in a variety of environments and climates (Guidi *et al* 2013).

Biofuels have become very important in the recent past due to the fact that developing countries are fighting to deal with the challenges of the ever skyrocketing prices of fossil fuels and global warming (Ndegwa *et al.,* 2011). Biofuel advancement initiatives have been productively executed in developed countries like the United States of America, Brazil, Canada, the European Union, Japan, and Australia among others (Sekoai *et al*, 2016). They are being sought as an alternative source of fuel. The demand for energy increases with growth in economic development as well as the world's population increase. The rise in the value of fossil coals is likely to put an additional burden on the net traders (Ndegwa *et al*, 2011). Biofuels are being perceived as a possible dynamism provider in the coming periods and, therefore several states are promoting strategies that inspire their manufacture and utilization (Sekoai & Yoro, 2016).

Biofuels have been endorsed in most industrialized and emerging nations whose intention is to expand their national energy source, lessen the reliance on extremely unstable fossil fuel values, improve admission to energy in remote parts of the country, and stimulate rural growth and lower carbon emissions (Koh & Ghazoul, 2018).

Energy is certainly a critical constituent of every nation's development and improvement of the living standards of its citizens (Lang & Barling, 2012). Given the current state of

technology, the world's vigor consumption and source cannot be considered maintainable, as a large portion of energy supply and use is reliant on finite resources such as fossil fuels (WHO, 2018). Since 1973, the global primary energy consumption has increased at an average annual pace of 2.0 percent (IEA, 2011).

As a result of the aforementioned difficulties, countries are investigating alternative energy sources that can help ease environmental modification. The energy sources can also lessen reliance on oil imports, and provide clean energy to the world's poorest and least developed countries. Germany, Sweden, Spain, and the United Kingdom have been pioneers in the adoption of biofuel energy. All policymakers are interested in developing alternative energy sources that are consistent with the notion of maintainable advancement. Biofuel is one of these alternate energy sources for meeting gasoline demand (Lal, 2015). Additionally, increasing oil charges, concerns about state energy safety, a desire to boost country proceeds, and a slew of fresh and enhanced skills have prompted a number of governments to take action. Governments such as in Indonesia, Malaysia, the Philippines, and Thailand, have established strong incentives for alternative fuel use (World watch, 2012).

There has been a lot written on the significance of biofuels in development and poverty reduction, and many claims have been made. Biofuels, according to Sage (2013), can aid in the alleviation of both poverty and climate alteration. According to de Keyser and Hongo (2015), biofuels can help fuel-importing developing countries diversify their economies. This is mainly achieved by allowing rural occupation formation and nourishment safety, reducing oil importations and generating foreign exchange savings. The biofuels also demonstrate a humid proportional benefit in manufacture, refining

national and local energy manufacture volume, and demonstrating a tropical comparative advantage in production. It has been stated that if biofuels can be generated sustainably, they can enhance livelihoods and contribute to rural development by providing a market for farmers, job opportunities, and domestic energy security.

These biofuel species can also be used to make bio petroleum, carbon-based fertilizers, and plant well-being foodstuffs with proper management, resulting in equitable access to energy. This also contribute to livelihoods, income, and growth without jeopardizing food production, ecosystem services, or productive land-use (Sage, 2013).

Biofuels have the potential to make rural regions more energy self-sufficient while also providing new and crucial revenue streams. However, attention needs to be put to safeguard that biofuels and the money they provide complement existing food production rather than obstructing it or raising demand for land-use change.

African countries have engaged in biofuel production for several years. Malawi has produced ethanol since 1970s, but this has been done at a small scale. Presently, numerous other African nations are generating it generally for manufacturing drives rather than petroleum. Most of these countries utilize sugarcane for biofuel production (Mitchell, 2011). In Kenya, biofuel production commenced in 1977 and ethanol amalgamation was adopted in 1984. This venture was however halted in 1995 due to the liberalization of the business mainly because of untenable profitable preparations and insufficient policy framework (Hunsberger, 2014). In the recent past, several external nations have appreciated great prospects in Sub-Saharan Africa nations, like Tanzania and Zambia, to obtain land to capitalize in large-scale biofuels plantations. Most of these countries produce for export and not for local consumption. This is ironic because most of

these African nations are the main traders of fossil fuels. The entire ethanol manufacture in Africa in 2006 amounted to less than 500 million litres with South Africa being the largest producer (Sekoai & Yoro, 2016).

Several countries in Sub-Saharan Africa have created large-scale biodiesel production plants using Jatropha. Burkina Faso, Tanzania, Mali, Ghana, Zambia, Madagascar, and Malawi are among them. The majority of Jatropha is either grown in plantations as a monoculture, in diverse cropping with additional food yields, or as a border plant. Jatropha hedgerows in Tropical Africa are projected to be 75,000 Kilometer (Km) long, yielding 60,000 t of seeds every year (Wiskerke, 2017). Rendering to the Annual Energy Viewpoint 2020 published by the US Energy Information Administration (EIA) (AEO, 2020), biofuel output in the United States is expected to rise gradually through 2050, owing to economic and policy factors. Current legislation and regulations are expected to increase biofuel output by 18% in 2050 compared to 2019.

According to the World Bioenergy Association (2020), the limits have had a significant influence on the energy sector in general, as global energy consumption has decreased by 18–25%. Industrial biofuel production was suspended in major international economies, and restrictions on people's movement led to one of the most significant drops in transportation fuel consumption in modern history. The bioenergy industry was severely impacted. Liquid biofuels are the most difficult kind of bioenergy to produce, while the solid biomass sector has proven resilient. Low fuel prices caused by the pandemic's effects have made biofuels harder to compete with conventional fossil fuels. Although certain farmers have shown resiliency by producing vital goods such as hand sanitizer. Due to worldwide movement restrictions, there has been a significant drop in demand for

transportation fuels, which has resulted in facility closures and reduced production. On the contrary, since there were no severe limitations in the conveyance of critical energy merchandises, most producers of solid biofuels such as wood pellets continued to produce with little alteration.

According to the United States Department of Agriculture, biodiesel plants in Canada were closed down in April 2020. The other operating biofuel plants, however, operated in the 50-70 percent capacity range during the initial part of the COVID-19 crisis. However, biofuel production in Canada has since improved, as export demand for ethanol increased in the European Union and export demand for biodiesel improved in the U.S. The report also shows Canadian exports of ethanol have increased suddenly, breaking back-to-back monthly records in May and June and realizing 15.6 million liters (4.12 million gallons) and 17 million liters of pure alcohol, respectively.

1.2 Statement of the Research Problem

Oil and ordinary gas are responsible for more than half of the biosphere's energy supply, with coal and peat accounting for another 30% and nuclear power accounting for 5%. Only 13% is derived from renewable resources. In most developing countries, the biofuel industry is seen as a way to boost economic growth and create long-term job opportunities, particularly in rural areas, owing to the conveyance segment, which is one of the largest patrons of fossil oils and accounts for roughly 23% of GHG (Greenhouse Gases) energy-linked releases (Lora, et al. 2010). Given the projected rise in energy demand by 3.1% per year in the next three decades and the constrained oil supply and the instability experienced in some oil-producing countries, the oil prices are not likely to fall soon (Khalili *et al*, 2019).

According to Hunsberger (2014), the drive for bio petroleum in Kenya is fueled in share by its promise to aid rural societies through socio-economic benefits such as providing a new source of income. Biofuel production has the potential to provide a new source of agricultural revenue in rural regions, as well as a source of infrastructure and development improvements. However, there is no adequate documentation on the engagement of smallholder farmers in the biofuel industry as a source of biomass material especially in Kenya (Duku *et al*2017).

Biofuels have continued to achieve popularity in the global agenda due to the increased demand for energy and the rise is certain to continue in the coming decades. Around 2 billion people in the biosphere have slight or no admission to modern energy (Bilgiç, 2017). Most of this population is domiciled in developing countries and are not able to leverage on the basic amenities and advantages of the modern forms of energy.

Bio oils have the probability to be an environmentally friendly source of energy due to their nature. There is a need to increase the productivity of commercially feasible, socially acceptable, and environmentally sustainable agroforestry-based biofuel production systems (Gajula & Reddy, 2021). Rural growth necessitates not only increasing energy delivery to encounter resident wants, such as providing cleaner cooking fuel or strengthening agrarian creation, but it also necessitates providing smallholder growers with replacements to supplement their proceeds, which liveliness marketplaces, over viable bio liveliness production. (Sola et al, 2016)

The Nanyuki-based biofuel company extract oil from the *Croton megalocarpus* nut, a canopy forest tree and use it to make organic fertilizer and environment-friendly fuel. The tree is one of the most often planted indigenous species in Africa's Great Rift Valley,

where it is primarily used as a border as well as for shade. The oil is extracted from the seed and has a variety of applications, including diesel fuel replacement in specific engines, leather curing, and soap production (Dekeyser, 2019). The remaining nuts are used to manufacture organic fertilizer, which is in high demand due to the need for Kenyan farmers to adopt more sustainable farming practices and the increased demand for organic fertilizers. As a result, cash income, food security, and access to affordable electricity are all enhanced. Empirical documentation of the biofuel feedstock production among smallholder farmers implications on their livelihoods is however not adequate. This research endeavored to fill the information gap by analyzing the dynamics of biofuel production among smallholder farmers in Laikipia East sub-County.

1.3 Objectives of the Study

1.3.1 General Objective

To examine the dynamics of biofuel feedstock production among smallholder farmers in Laikipia East sub County in Laikipia County.

1.3.2 Specific Objectives

Specific objectives of the study were;

i. To establish the different biofuel feedstock species used in biofuel production among smallholder farmers in Laikipia East sub-County, Laikipia County
ii. To assess the drivers of biofuel adoption among smallholder farmers in Laikipia East sub-County, Laikipia County.
iii. To assess the socio-economic impacts of biofuel production among smallholder farmers in Laikipia East sub-County, Laikipia County.

1.4 Research Hypothesis

H_0: There is no statistically significant socio-economic impact of biofuel production among smallholder farmers in Laikipia East sub-County, Laikipia County.

1.5 Justification of the Study

The research is of importance to the farmers as it sheds light on the socio-economic impacts of biofuel production among smallholder farmers. This has the potential to generate interest to other farmers and in turn lead to the growth of the industry.

The research is important to the Ecofix Kenya Group organization. The study will provide more evidence on the socio-financial influences of biofuel production amongst smallholder farmers. The study is useful to regulators and policymakers in the biofuel business, can inform them on formulation of policies to manage the industry. The study is also expected to be useful to researchers in generating knowledge that will help to expand the benefits of biofuels for livelihood.

1.6 Scope and Limitations

1.6.1 Scope

The research focused on the dynamics of biofuel production among smallholder farmers in Laikipia East sub-County in Laikipia County. The study evaluated the drivers of biofuel adoption among smallholder farmers in Laikipia East sub-County Laikipia, established the different species of crops used in biofuel production among smallholder farmers in Laikipia East sub-County Laikipia and the socio-economic impacts of biofuel production among smallholder farmers in Laikipia East sub-County, Laikipia.

1.6.2 Limitations

Most of the biofuel species in the area of study were on people's farms grown as a boundary hence the coverage, which reduced the area of focus as well as the number of investors who could be covered. The study was also limited to Laikipia East Sub-County because that is where most of the biofuel production was taking place. Again, the study mainly focused only on farmers working with Ecofix Kenya, the only company dealing with biofuel in the Mt Kenya region and in particular Laikipia. The study only focused on biofuel species and economic drivers of biofuel production and did not explore cultural drivers.

1.7 Definition of Terms

Species; Refers to the group of living organisms that are used in the biofuel industry.

Socio-economic impacts; Refers to the results or effects on social process, educational and quality of life benefits on population, demographics, land use and economy.

Biofuel; This term refers to fuel created by modern organic procedures such as cultivation and anaerobic absorption, as divergent to environmental procedures like those responsible for the creation of fossil oils such as ember and fuel from primeval organic substance.

Feed stock; Refers to the raw materials used in the biofuel production.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The section shows the prose appraisal in comparison to the dynamics of biofuel production. The literature is presented as; the concept of biofuel, biofuel and population, impact of biofuel production, types of bio fuel, theoretical framework and conceptual framework.

2.2 The Concept of Biofuel

Biofuels are biological main and/or subordinate oils generated from bio form that can be used to generate current vigor either by burning or through other skills. They include energy crops produced specifically for energy production, as well as multipurpose plantations and by-products (residues and wastes) (FAO 2011). They are renewable Biomass-derived liquid, solid, or gaseous energy sources (GTZ/MOA, 2008). Biofuels create fewer hazardous air pollutants and greenhouse gases than fossil fuels, and they can be produced anywhere with enough feedstock.

Energy is unquestionably one of the most significant components in any country's growth and improvement of the masses' living conditions. Given the way existing technologies are applied, the biosphere's energy usage and source cannot be considered maintainable (Jovanovic, et al., 2010), owing to the element that much of energy source and usage is reliant on finite sources like fossil oils (WHO, 2018). Since 1973, the biosphere's main energy claim has grown at an annual degree of 2.0 percent on a regular (IEA, 2011).

Because of the various challenges, countries are pursuing alternative energy sources that can help to mitigate temperature alteration, decrease oil importation dependency, and offer unsoiled energy to the less industrialized and impoverished nations. Policymakers

want to find alternative energy sources that are well-matched with the idea of maintainable growth. One of these alternative energy sources is biofuel. Furthermore, rising oil costs, concerns about nationwide energy safety, a desire to boost country profits, and a slew of fresh and better technology have prompted numerous administrations to establish strong inducements to inspire the usage of substitute oils (World watch, 2012).

Biofuels have been hailed as having the ability to reduce greenhouse gas releases, improve energy safety, and stimulate country growth (IIASA, et al., 2009). In most developing countries, the biofuel industry is seen as a way to boost economic growth and create long-term job opportunities, particularly in rural areas, owing to the conveyance subdivision, which is one of the largest customers of fossil oils and accounts for roughly 23% of GHG (Greenhouse Vapors) energy-connected releases (Lora, et al., 2010).

2.3 Types of Biofuels

Table 2.1 breaks biofuels down by group and then looks into their usages, energy thicknesses, and conservatory gas influences.

Table 2.1: Biofuels, Feedstock, Energy Density and their greenhouse gas impacts

Fuel	Feedstock	Energy Density (megajoules/kilogram)	Greenhouse Gas CO_2(kg/kg)	Notes
First Generation				
Bioalcohol	Starches from wheat, corn, sugar cane, molasses, potatoes, other fruits	By Type	By Type	
Ethanol		30	1.91	
Propanol		34	N/A	
Butanol		36.6	2.37	
Biodiesel	Oils and fats including animal fats, vegetable oils, nut oils, hemp, and algae	37.8	2.85	
Green Diesel	Made from hydrocracking oil and	48.1	3.4	Chemically identical to fossil fuel diesel

Fuel	Feedstock	Energy Density (megajoules/kilogram)	Greenhouse Gas CO_2(kg/kg)	Notes
	fat feedstock			
Vegetable Oil Castor Oil Olive Oil Fat Sunflower Oil	Unmodified or slightly modified	By Type 39.5 39 32 40	By Type 2.7 2.8 N/A 2.8	
Bioethers	Dehydration of alcohols	N/A	N/A	These are additives to other fuels that increase performance and decrease emissions, particularly ozone
Biogas	Methane made from left-over crop substantial through anaerobic digestion or bacteria	55	2.74 (does not take into account the direct effect of methane, which is 23X more real as a GHG than CO_2	Same properties as methane from fossil oils
Solid Biofuels Wood Dried plants Bagasse Manure Seeds	Everything from wood and sawdust to garbage, agricultural waste, manure	By Type 16-21 10-16 10 10-15 15	By Type 1.9 1.8 1.3 N/A N/A	This category includes a very extensive diversity of resources. Compost has little CO_2 emissions, but high nitrate releases.
Second Generation				
Cellulosic ethanol	Usually made from wood, grass, or inedible parts of plants			
Algae - based biofuels	Numerous diverse oils formed from algae	Can be used to harvest any of the oils overhead, as well as jet oil	See specific fuels overhead	More luxurious, but may produce 10-100X more petroleum per unit area than other bio oils
Biohydrogen	Made from algae breaking down water.	Hydrogen compressed to 700 times atmospheric pressure has energy density of 123	Does not have any greenhouse effect.	Used in place of the hydrogen produced from fossil fuels
Methanol	Inedible plant matter	19.7	1.37	More toxic and less

Fuel	Feedstock	Energy Density (megajoules/kilogram)	Greenhouse Gas CO_2(kg/kg)	Notes
				energy dense than ethanol
Dimethylfuran	Made from fructose found in fruits and some vegetables	33.7		Energy density close to that of gasoline. Toxic to respiratory tract and nervous system
Fischer-Tropsch Biodiesel	Waste from paper and pulp manufacturing	37.8	2.85	Process is just an elaborate chemical reaction that makes hydrocarbon from carbon monoxide and hydrogen

Source: http://biofuel.org.uk/

2.4 Species used for biofuel

2.4.1 Biofuel Feed Stocks species

The raw material or biomass used to make biofuel is referred to as a biofuel feedstock. Ethanol, which is formed from the fermentation of sugary/starchy crops like sugar cane and corn, and bio diesel, which is made from oil yields like oil palm and soybeans, are the two most common liquid biofuels utilized in the transportation industry today (IEA 2011).

There are potentially viable biofuel feed stocks in Kenya that depend on the history of production and climatic suitability (GIZ/MOA, 2013). These are coconut, castor, jatropha, cotton, rapeseed, croton, and sunflower. Others that can be applied are maize, sugar cane, palm and soya, although these have the potential to pose competition on land-use and food security.

Castor has been highly taunted as a biodiesel source because of its high oil content and its ability to grow in areas with little water. It is used in industrial, medicinal and automotive

industries. It is also suitable in agroforestry use. However, it is highly invasive and not very tolerant to prolonged drought.

Cotton is mostly associated with its use in the textile industry. Its residue produces cotton seed oil and animal feeds. Cotton fibre is useful in the medical sector for making cotton wool, gauze and cotton swabs. Its oil is used to make soaps and cosmetics. It is non-invasive and can tolerate drought.

Croton is used in medicine, as an animal feed and as a source of fuel wood. It can be used to treat stomach problems and pneumonia. The seed has a high oil (30%) and protein (50%) content (GIZ/MOA, 2013). It is a good fence and is used for shade. The leaves are good for compost because of the elevated content of nitrogen and phosphorus. Croton is fast-growing and can do well in difficult climatic conditions. It is not fed on by animals hence survives well. It is used to delineate land, as a wind breaker as well as an erosion control measure.

Jatropha has been highly publicized as a source of biofuel oil. It has many uses which include medicinal, in the textile industry for tie and dye. It has been used in agroforestry. In semi-arid areas, it is used to control soil erosion, and as a hedge. The seed cake is high in nitrogen hence used to improve soil fertility. However *Jatropha* is considered invasive.

Rapeseed is grown for its oil and as an animal feed. The oil has numerous uses especially in the paint industry. It is used in Europe as a source of biodiesel. Rapeseed is used as a cover crop that protects the soil and subdues weeds especially in Laikipia where it is commonly grown by wheat farmers for this purpose.

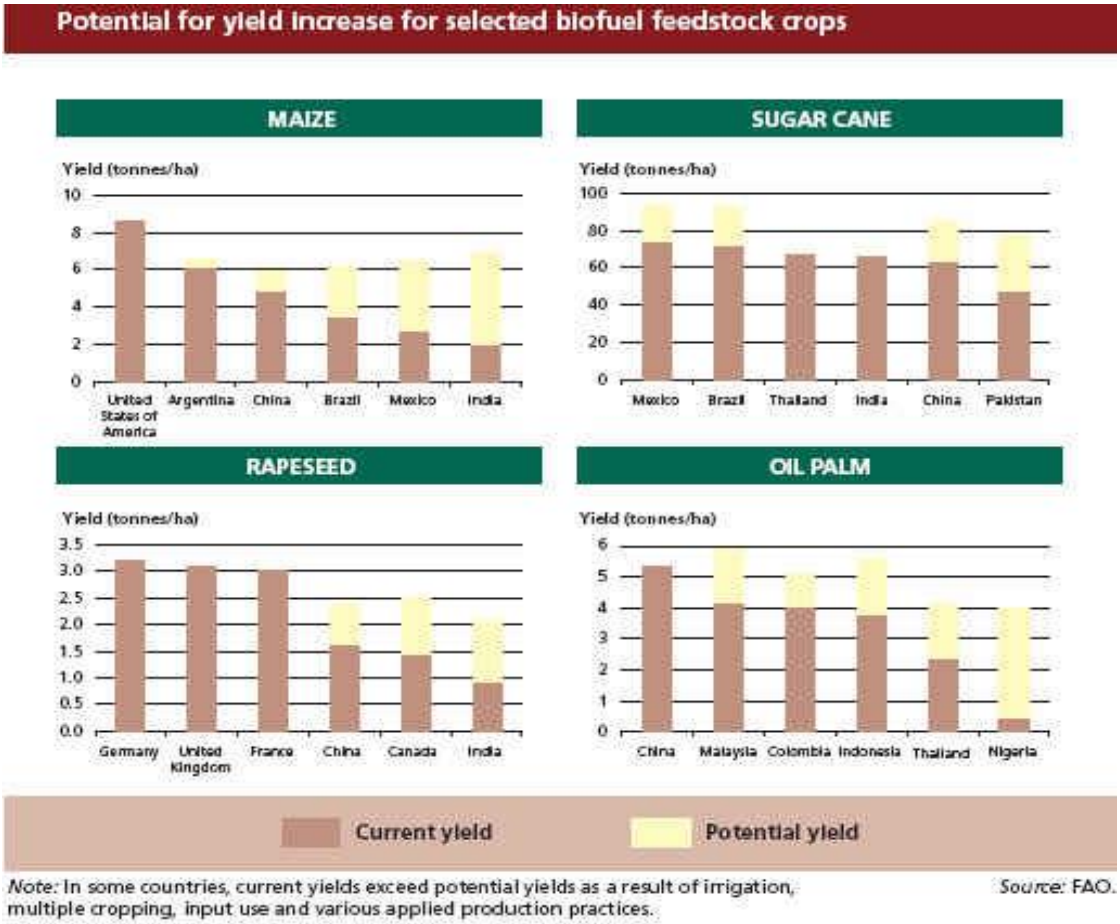


Figure 2.1: Selected Biofuel feedstocks in selected Countries

2.5 Drivers of adoption for biofuel

2.5.1 Environmental Conservation

The impacts of biofuel on the environment depend on the type of feed stock used, method and scale of production (GIZ/MOA 2013). The air quality and health benefits of biofuels are quite enormous. The fact that biofuels produce significantly lower air emissions from exhausts as compared to other emissions from other sources throughout the life cycle is quite important for the environment and significant for climate change mitigation.

Biofuels can aid in soil erosion control and reclamation of marginal lands for agricultural purposes. However this can bring about negative impacts in the case of large-scale

plantations in an environmentally significant area like a forest. Another risk would emanate from the invasiveness of some species such as Castor and Jatropha.

Depending on where and how those crops are cultivated, biofuels can have a wide range of environmental effects, but climate advantages can be increased at a minimal cost (Field, 2009). One of the primary motivations for biofuel production is to minimize greenhouse gas releases and ameliorate the consequences of fossil fuel-induced worldwide heating. Growing crops for biofuels is often assumed to reduce greenhouse gas releases since they eliminate carbon dioxide from the air directly.

It is important to highlight that several recent studies have indicated that not all biofuels and skills have significant environmental and social benefits when compared to fossil fuels (Melillo, et al., 2009; Ulgiati, 2011). The benefits and drawbacks are dependent on the local characteristics of the place where biofuels are produced and used (Groom et al., 2015). According to FAO 2011, the quantity of emissions created throughout the manufacturing process must also be measured, and an equilibrium must be struck amid unswerving greenhouse gas reserves, releases, and possibly beneficial by-products produced in bio petroleum manufacture.

2.5.2 Importance of Biofuels in Transport sector

Because the transportation industry is 93 percent reliant on crude lubricant (IEA 2011), discovering a dependable replacement is critical in rule creation. Colombia, Canada, the European Union (EU), India, the United States, and the Thailand are among countries that have developed and used biofuel. Biofuel has some advantages over other options, including the fact that (i) it can be utilized in present engines without requiring complex adjustments; and (ii) it does not necessitate lengthy studies or research. Nonetheless, the

impact of biofuel on sustainable development is a hot topic of discussion, and it has been produced in enormous quantities with consistent results.

In current engines, biofuels are blended with conventional fuels. Blending limitations in the EU are determined by fuel specification rules that assure compatibility with conventional engines and refueling infrastructure. Current fuel regulations allow for up to 7 percent Fatty Acid Methyl Esters (FAME), a mixture of fatty acids (the most popular kind of biodiesel, B7) in fossil-fuel diesel and up to 10 percent ethanol (E10) in gasoline. Even at larger quantities, such as 30 percent v/v, hydro treated vegetable oil (HVO) may be mixed with standard diesel (30 percent HVO, 70 percent diesel). The regulatory environment, on the other hand, is fragmented throughout the EU. Biofuels may function with existing engine and powertrain technology and can be injected straight into the tank of any vehicle at low percentage mixes for example B7 or E5 (5 percent ethanol, combined with petrol). To function smoothly with greater mixes, car engines and powertrains must be adjusted. Even when vehicles are compatible with higher blends (E10 can be used in 85 percent of EU automobiles and all new cars made after 2010 at the latest)8, market uptake does not always follow: consumer choices have a big impact in changing the mix of gasoline volumes supplied (Panoutsou *et al.*, 2021).

2.5.3 The global growth of Biofuel

There has been a continued decline in fossil fuels as well as increased environmental degradation. This in turn prompted a worldwide curiosity in the formation of an environmentally friendly alternative form of energy with low carbon and which enhances and promotes environmental sustainability. Biofuels are rated as the best substitute energy source because they are generated from sustainable energy crops (Pradhan *et al.*, 2011).

The global generation of bio-oils has been steadily rising considerably over the previous few years, ranging from 20 billion litres in 2001 to slightly above 110 billion litres in 2011 (Esterhuizen, 2013).

In developed nations where conservatory air emissions have been the main issue, the bio petroleum segment has remained heavily bolstered to reduce the problem. This has resulted in a massive increase in bioethanol and biodiesel output. According to the US Environmental Protection Agency in 2010, biofuel output is predicted to increase to 222 billion litres by 2021, with biodiesel and bioethanol accounting for 81 percent and 19 percent, respectively. It has been noted that highly industrialized and developed countries such as the United States of America, Brazil, the European Union, Australia, and Japan produce a large share of the biosphere's biofuels. This is done in order to reduce their carbon footprints. Biofuels, on the other hand, are seen as a promoter of infrastructural growth in poor and underdeveloped countries like Africa, enhancing reduction and overreliance on fossil fuels, lowering global oil values, improving the landmass's energy segment, and creating job opportunities for the rural population.

2.6 Socio-economic impacts of Biofuels Production

2.6.1 Impact on Livelihood

Biofuels have various effects on the livelihood of farmers. To begin with, biofuels have received a lot of interest because they offer additional rural jobs and better pricing for farmers. Empirical studies conducted recently acknowledge the importance of biofuels in the creation of employment and increase in income among the farmers. A study by De la Torre Ugarte *et al.,* (2017) projected that the increasing production of ethanol was estimated to contribute positively to employment. The increased demand for biofuels has

led to the growth of the agricultural sector by increasing production which result to advanced service charges and earnings and in particular where cultivation is labour concentrated (Koh & Ghazoul, 2018).

Biofuels do not only come with positive effects but also have negative impacts. According to Dauvergne and Neville (2014), the production of biofuel marginalizes the subsistence farmers as well as disregards their interests. According to the United Nations the benefits of biofuels could be outweighed by it dangers since biofuels are related to loss of biodiversity and an increase in food prices. In 2011 the Food and Agricultural Organization (FAO) recorded the uppermost Food Price Index in over 30 years which came along with the worldwide financial recession. The increasing values are likely to cause nourishment safety issues as well exacerbating poverty severity worldwide. More so biofuels are always in competition with other crops for land and water.

One of the greatest persistent concerns facing the world is population expansion and finding effective strategies to deal with this realism. By 2025, the world populace is expected to exceed 8 billion people (UN, 2011), with developing nations accounting for the majority of this increase (Lal, 2015). Furthermore, around a third of the biosphere's people still rely on non-profitable oils (United Nations, 2007). Approximately 1.4 billion persons, or more than 20% of the world's people, lack access to electrical power, while 2.7 billion persons, or almost 40% of the world's people, rely on old-style biomass for cookery (IEA, 2011). The growing body of scientific information demonstrating the crucial necessity to address climate alteration has shifted global and nationwide perceptions of these subjects (IIASA, et al., 2009).

2.7 Biofuel initiatives in the world

2.7.1 Global Biofuel Initiatives

The International Energy Agency (IEA, 2019) reported that worldwide bio-petroleum manufacture improved by about 10 billion litres in 2018 to achieve a highest of 154 billion litres. This was twice the increase achieved in the year 2017. It is projected that the production will grow by 25% in 2024, which will be a positive growth from 2018 due to an increase in demand predictions in Brazil, the United States and even China. Likewise, biofuels delivered 93% of global renewable energy, the rest was covered by renewable electricity— mostly solar. According to IEA report the biofuel segment of renewable energy in transport will hit about 90% by 2024.

In the global economy, the United States and Brazil dominated the biofuels market, accounting for over 87 percent of global production in 2018. According to the World Gas and Renewables Evaluation 2019 issued by Italian oil and gas company Eni, biofuels were produced at a rate of 2,616 thousand barrels per day.

United States

The United States of America leads the world in biofuel production and accounted for about 38 percent of the global production of biofuel in 2019 with a production of 1,557 petajoules (Sonnichsen, 2021). The US is also a main producer of biodiesel. In 2018, the United States generated roughly 45.5 percent of global biofuel production (NS Energy, 2019). America is also the earth's biggest manufacturer of bio petrol, accounting for 55.4 percent of global production of about 1,047 thousand barrels per day. By the end of 2018, the country had produced around 136.18 thousand barrels of biodiesel per day, making it the world leader with a 19.4 percent market share.

Corn is the main feedstock for gasoline-ethanol manufacturing in the United States, whereas soybeans are used to make biodiesel. Rendering to the United States Department of Agriculture's (USDA) Grain Crushing's and Co-Harvests Manufacturing report, more than 5.55 billion loads of maize were crumpled for the manufacture of ethanol petroleum in 2018. According to the Energy Information Administration (EIA), the United States generated roughly 16.061 billion tons of ethanol in 2010, with Iowa leading the way with 4.328 billion tons each year.

Brazil

According to the 2018 production of 693.2 thousand barrels per day, Brazil was ranked second among the major biofuel producers (NS Energy, 2019). In 2018, the country provided 26.5 percent of the biosphere's entire bio petroleum making. It is also the world's second-largest manufacturer of bio petrol, with a 31.5 percent share equal to around 595.35 thousand barrels per day.

Brazil is the world's second-largest producer of biodiesel, accounting for 14.1 percent of global production, or around 99,000 barrels per day. Sugar cane is used to make ethanol and soybeans are used to make biodiesel in this South American country. Bagasse is also widely utilized in Brazil as oil in sugar mill co-generation plants to encounter on the spot energy requirements while also providing surplus electricity for export.

In 2018, the entire national demand for ethanol for gasoline and other aims was projected to be around 28.72 billion litres. Brazil is expected to have formed 30.755 billion litres of ethanol in 2018, up 9% from the corrected total for 2017. Brazil's outstanding development in bioethanol production and its use is can be attributed to its tropical location, expansive land area, and appropriate climatic conditions for sugarcane cane

growing. Sugarcane is approximately twice as effective for ethanol production as corn, its yield is estimated at 800 gallons of ethanol per acre.

Brazil as a country has had a policy on ethanol fuel dating as early as World War II when gasoline was deemed expensive. The mandatory ethanol blend was 50% by volume at that time. Gasoline prices dropped after the war, and also the use of ethanol blends, which were only periodically used. The oil crisis triggered by OPEC in 1975, convinced the Brazilian government that dependence on foreign oil was unsafe and this led to the establishment of the Nation Alcohol Program (Programa Nacional do Alcool).

Germany

Germany is the world's third-largest biofuel creator. In 2018, it formed 75.8 thousand barrels per day, accounting for 2.9 percent of worldwide bio petroleum manufacture volume (NS Energy, 2019). German industries produced 3.2 million tonnes of biodiesel in 2018, conferring to the German Suggestion of Biodiesel Creators (Verband der Deutschen Biokraftstoffindustrie, VDB). Rapeseed and leftover cooking oil were the chief basic resources used in the manufacturing of this petroleum. Germany exports an important amount of its biodiesel.

According to the statistics provided by the Federal Office of Economics and Export Control in 2018, about 2.21 million tonnes of biodiesel were spent in Germany in the year, and substantial volumes were exported in other places in Europe.

Leading countries based on biofuel production worldwide in 2020

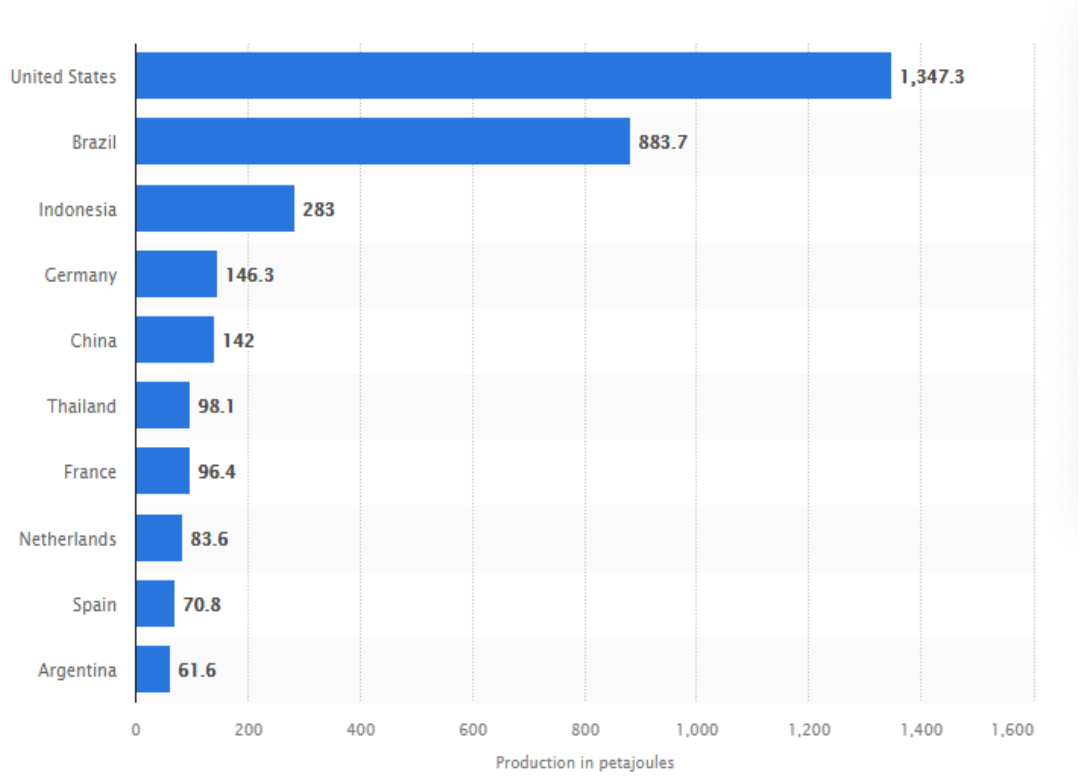


Figure 2.2: Leading countries based on biofuel production worldwide in 2020*(in petajoules)

Source: EIA (2021), the Environment Impact Assessment Report.

2.7.2 Biofuel in Africa

Evolving Africa's biofuels potential has been a long and slow process with the continent's several country-by-country development plans that have taken long in government desks without conclusive decision making. Many African governments are attempting to attract biofuels investment and boost local participation in production and processing. In most African countries, biofuels have the potential to improve and expand the upcoming for energy safety and rural growth. In Africa, innovator biofuel corporations are developing and applying novel commercial replicas that focus on limited indigenous agriculturalists and businesses. African governments can help these projects

by providing legal and institutional support, as well as practical leadership for investors and small and medium-sized businesses, and by leveraging international resources.

Africa is a perfect environment for the development and production of a number of feedstocks like Jatropha. Nevertheless, the African continent is devoid of the type of strong central government structure that is requisite to financially support the huge investment of the growing biofuel industry. This means that only a few countries in the continent have set up progressive biofuel initiatives. Some other countries have started from foreign interference such as land grabbing and speculation which has in return negatively affected the local economies. Some of the African Countries that have invested in bio petroleum manufacture are as follows.

Mali

Mali is amongst the deprived countries in Africa with an extremely low and unequal income distribution. It is a land-locked country with very few export opportunities. 60% of its land area is either a desert or semi-desert. About 12% of the rural population has access to electricity, which is important for any meaningful productivity and development to take place.

Various NGOs and European firms are interested in the development of biofuel feedstocks, primarily through small-scale operations in Mali, a landlocked West African country. The majority of the production takes place within walking distance of the corporation's or NGO's dispensation amenities. Mali-Folkecenter Nyetaa (MFC) is a Malian NGO that specializes in renewable energy and environmental protection. The organization has been in operation since 1999 to develop pilot projects to showcase that

pure Jatropha oil can be used as a fuel to enhance Mali's future development sustainably and to benefit the local people economically.

The MFC provides electricity to the surrounding communities, which is generated by power floras that use jatropha oil kernels. The scheme is part of a 15-year electrification plan, with the goal of generating 300 KW of power providing power up to 10,000 rural households. More than 100 hectares of jatropha homestead would be raised and used as feedstock for the power plant, according to the plan. This effort is expected to help the rural people better their living conditions.

Mali Biocarburant SA is a private Dutch firm whose mission is to harvest biodiesel for the nation's national marketplace. They want to get their feedstock from smallholder farmers who cultivate jatropha on 3000 hectares (ha). The company has invested in locally appropriate research and development, and is also challenging new habits to recover the productivity and sturdiness of multi-function stages, such as the use of portable engines powered by biodiesel from jatropha that can control a variety of rural uses like grain grinding and electricity generators.

Jatropha Mali Initiative (JMI), a French-Malian joint project was established in 2007 with the purpose of biodiesel production, but is currently being used to produce jatropha oil for both local and national markets. This organization functions an obliging society for seed assortment and oil discharge that comprises 1300 limited farmers on 1300ha. Other seeds are collected from the farms. JMI trains the farmers on farming, and they ensure the purchase of the seeds produced. The establishment of Mali's National Agency for Biofuels Development (ANADEB) in mid-2009 is a shift in the right direction and

guarantees a bright future for biofuel out-grower schemes (Boccanfuso & Savard, 2012). The future of large-scale production of biofuel in the country is not guaranteed.

Mozambique

Mozambique is one of Africa's poorest countries. Procana, a British company, plans to invest US$510 million on 30,000 hectares of land, 60 percent of which will be used for sugarcane feedstock and the rest for a bioethanol plant and accompanying infrastructure. There are several biofuel production enterprises that have been realized in Mozambique in the recent past. These include the Ndzilo Production Plant which utilizes cassava to produce ethanol and has a capacity of two million litres (Amigun *et al.*, 2011). Jatropha oil seeds use is very popular in Mozambique due to its benefits such as its ability to withstand very harsh and dry weather conditions. Other Companies like Petromoc and Sun Biofuels have been reported to have set up biodiesel generation factories in the recent past with the aim of enhancing the nation’s energy segment. The Mozambican management has also made bioethanol blends of 5–10 percent (v/v) with gasoline a reality.

Sugarcane out growers in Mozambique are expected to expand by 5 to 11,000 hectares. For business and food security considerations, Procana is limiting communities to planting cane on no more than a third of their agricultural areas. By 2022, the corporation plans to put about 4000 hectares under out growers, who will be given professional assistance, knowledge, farm inputs, and irrigation infrastructure.

Mozambique Principle Energy, a renewable energy company is planning to establish a combined bioethanol facility. It has a 20,000ha estate complemented by huge and small-scale out cultivators. This is expected to increase competition and improve quality

amongst the farmers. Although there is a likelihood of disenfranchising small-scale farmers on issues of support, prices and market access. Other small-scale biofuel projects operating in Mozambique are Elaion Africa, a German business that targets to grow jatropha on 1000ha, with prospects for limited farmers.

Tanzania

There are various businesses, NGOs, and limited agriculturalists operating bio-oil initiatives in Tanzania, East Africa (Banks & Schäffler, 2013). These companies are currently testing a range of pioneering biofuel generation models, which focus on the use of limited initiatives and clients additional along the worth chain.

FELISA (Farming for Energy for Better Livelihoods in Southern Africa) is a Tanzanian-Belgian joint company with the primary goal of producing biofuel from palm oil. The corporation wants to plant 10,000 hectares of oil palm, with half of it coming from out cultivators who will obtain financial and technical assistance.

Diligent Tanzania Ltd is a private Dutch business operating in Tanzania. The company has been generating *J.Carcus* oil since 2005. It depends solely on out growers and has contracted smallholder farmers for production. Currently, they have around 5000 suppliers who grow jatropha as a farmhouse on outlines, hedges and tainted land. The contracted farmers purchase their seeds and in exchange, they receive free planting materials and technical advice from the company (Mitchell, 2011). The company further guarantees to buy seeds at the lowest price for a duration of 10 years.

Sekab Bioenergy Tanzania Ltd, a Swedish bioethanol firm, now plans to expand extensive sugarcane manufacture for bioethanol generation on a 22,000-hectare plot in eastern Tanzania's Bagamoyo District, as well as another 500,000-hectare plot in the

nearby Rufiji District (Vermeulen et al, 2009). Sekab intends to re-transfer producing lands to small-scale farmers through a permit block-farm prototype in the future. In this model, the contracted farmers reach an agreement to abide by the company measures and they in return secure a guaranteed market at agreed prices.

Table 2.2: Biofuel production from agricultural waste in sub-Saharan African Countries

Country	Feedstock	Biodiesel Yield (ML)	Bioethanol (ML)
Benin	Cassava	-	20
Burkina Faso	Sugarcane	-	20
Ivory Coast	Molasses	-	20
Ghana	Jatropha	50	-
Guinea	Cashew	-	10
Mali	Molasses	-	20
Malawi	Molasses	-	146
Kenya	Molasses	-	413
Ethiopia	Molasses	-	80
Niger	Jatropha	10	-
Nigeria	Sugarcane	-	70
Sudan	Molasses	-	408
Swaziland	Molasses	-	480
Senegal	Molasses	-	15
Tanzania	Molasses	-	254
Togo	Jatropha	10	-
Uganda	Molasses	-	119

Source: Sekoai et al, 2016

2.7.3 Biofuel production in Kenya

Several emerging republics including Kenya have intentions to expand their local energy source so as to lower the overdependence on overpriced fossil fuels, improve admission to energy for the country, stimulate rural development and to lower carbon emissions Kenya, with its limited oil reserves and excellent climatic conditions for developing biofuel, could limit the shock of high fuel prices by developing own supply of locally produced biofuel. Kenya's policy supports the development of biofuel according to

Sessional paper No. 4 of 2004, The Energy Act of 2012 and the Biodiesel strategy developed by the Biodiesels Committee.

Kenya's main energy source sources are mostly biomass (68 %), Petroleum (22 %), electricity (9 %) and char at less than (1%) (Ndegwa *et al.,* 2011). The energy sector consequently displays a significant dependence on diminishing biomass energy reserve to cater for energy demands particularly for the rural population and substantial reliance on oil to service the contemporary financial demands. This means that investment on biofuels especially for the transport sector can improve this condition and as a result save on foreign currency, enhance rural development and lower greenhouse gases (GHG) emissions from fossil fuels.

The local biofuel initiatives include Help Self-Help Centre and Ecofix Kenya.

Help Self-Help Centre

This is a Kenyan NGO based in Naro Moru in Central Kenya, working on sustainable agriculture, natural resource management and business development initiatives for farmers (Takase *et al,* 2021). They produce bio-diesel and vegetable oil for commercial purposes. In this project the farmers are able to use croton seed waste as organic fertilizers and this has helped the smallholder farmers to improve crop harvest. Due to its success and affordability, farmers have adopted organic farming in their practice. This has assisted farmers not only to increase their yield but also to sell excess harvest in the local market thus improving their livelihood. Therefore, farmers have been able to produce additional income and savings.

Seedcake extracted from croton and cape chestnut is traded at subsidized rates to farmers who use it as animal feed. This has led to an improvement in dairy and meat production,

the households have produced surplus milk and meat, on top of meeting their subsistence needs. The project has made a positive contribution towards increasing food safety both at home and community levels.

Ecofix Kenya

Currently, Ecofix Kenya, a Company based in Nturukuma Location, Laikipia East Sub-County in Laikipia County extracts oil from the nuts of mainly the *Croton megalocarpus* tree and uses it to manufacture biofuel, organic fertilizers, seed cake and vinegar. The tree is one of the most well-known indigenous species in Africa's Great Rift Valley. The *C. megalocarpus* nut provides an alternative environmentally acceptable fuel source. This is a renewable energy source. The extracted fuel is sold as a diesel alternative for engines like generators and water pumps.

Ecofix Kenya which produces biofuel, foliar spray and organic fertilizer from *C. megalocarpus* nuts has around 6000 to 7000 farmers supplying croton nuts at free will from Laikipia County. This is done in a bid to provide the farmers with an alternative and guaranteed source of income as compared to meager incomes they got from yields from traditional crops in the area.

In the year 2017, the company reported a total harvest of 290, 000 tons harvest of *C. megalocarpus* nuts and the figure is expected to rise in the coming years as more farmers become aware of the initiative. The company is also involved in tree planting in the area it operates in. In 2017, about 64,000 tree seedlings were planted, and up to date, 150,000 seedlings have been planted in order to conserve the environment and boost nut production.

The Croton Nut Oil (CNO) bio petroleum, which can substitute diesel in slow-rotating engine oil and has no biochemical additions, was developed from the seeds. The oil burns cleanser than standard oils locomotives, diesel petroleum, and has minimal sulfur content due to its natural qualities. *C. megalocarpus* Nut Oil is appropriate for usage in diesel machines that rotate at 1,400rpm or a lesser amount, like motionless diesel producers, tractors and water pumps according to sufficient consumer testing in central Kenya and laboratory investigations.

Kenyan farmers commonly use the *C. megalocarpus* tree as a windbreak or a fence. Recently, the plant is providing a new biofuel manufacturing possibility. Despite the fact that the *jatropha* plant had been chosen as Kenya's future biofuel hope. The *C. megalocarpus* tree, also identified as Mukinduri in central Kenya and Chepkeleliet, Lemaruguet, Masineitel, Mkigara, Mlalai, Muhande, and Musine in other parts of Kenya, is a non-food crop that promises equal opportunities in terms of biofuel quantity and quality. Currently a lot of research is on-going in the country to identify the optimal mix of non-food crops to use in making biofuel to complement the nation's massive need for fossil oils, which costs Sh120 billion per year to import. The demand for bio petroleum is fueled in partly by the possibility for it to benefit rural areas by providing a new source of revenue.

Among the other crops found as suitable for biofuel generation, *C. megalocarpus* has the greatest fuel content, surpassing rapeseed, avocado, and *J. carcus*. As concerns about the viability of *J. carcus* grow, the usage of *C. megalocarpus* nuts for biodiesel is understood as a great possibility for Kenya's renewable energy industry. Proponents of *C. megalocarpus* fuel argue that, even if it costs the same as fossil fuel, it is superior since it

benefits farmers. It has been noted to boost the economy as well as serves as a source of foreign exchange. The usage of bio petroleum will also improve Kenya's ability to benefit from the global carbon trade, which rewards projects that reduce carbon dioxide emissions into the atmosphere. Despite its traditional uses as a windbreak, a barrier, or a source of charcoal, the *C. megalocarpus* tree is progressively being destroyed to make space for food crops in some regions of the country due to increased overcrowding.

2.8 Theoretical Framework

2.8.1 Rodger's Diffusion of Innovation Theory

Everett Rogers proposed the concept of diffusion of innovations in 1962, and it aims to clarify in what way, wherefore, and at what degree fresh philosophies and skills spread. Dispersal, is the procedure over which an invention is dispersed amid the contributors in a communal scheme over a period (Rogers, 1962). Rogers goes on to say that the dissemination of a new idea is influenced by four primary factors: the invention itself, message stations, period, and a communal scheme, and that this procedure is primarily reliant on humanoid wealth (Rogers, 1983).

To be sustainable, the invention must be extensively accepted. Modernizers, initial adopters, early mainstream, late mainstream, and stragglers are the dissimilar kinds of adopters (Noel, 2019). According to Rogers, the traits and characteristics of the innovation are vital in influencing how it spreads and how quickly it is adopted (Rogers, 1995). He observes, drawing on the effort of Thomas and Znaniecki (1927), that what matters is what possible adopters see as the features of a novelty (Kunreuther & Pauly, 2012). In the circumstance of technical invention, which encompasses practically all of the inventions researched, the rate at which it is implemented is critical for structural

growth and expansion (Noel, 2019). According to Rogers (1995), there are two mechanisms to consider: a hardware feature, which consists of an instrument that physically exemplifies the skill, and a software aspect, which consists of the tool's information base. Comparative benefit, compatibility, difficulty, trialability, and observability are five fundamental features of an innovation, according to Rogers, that influence its diffusion.

Innovative technologies have been created to replace fossil oils and contribute to the decrease of conservatory gas releases linked with their use, according to this study. Biofuels are particularly essential as a means of substituting the use of petroleum while yet keeping the same level of vehicle performance. Other bases of 1st group bio-oils, like soybeans, sugarcane, rapeseed, and maize amid others, put weight on food marketplaces, pay to water shortage, and hasten forest destruction.

2.9 Conceptual Framework

This section schematically shows the flow of biofuel. The small holder farmers and biofuel production have a symbiotic relationship as shown in figure 2.3.

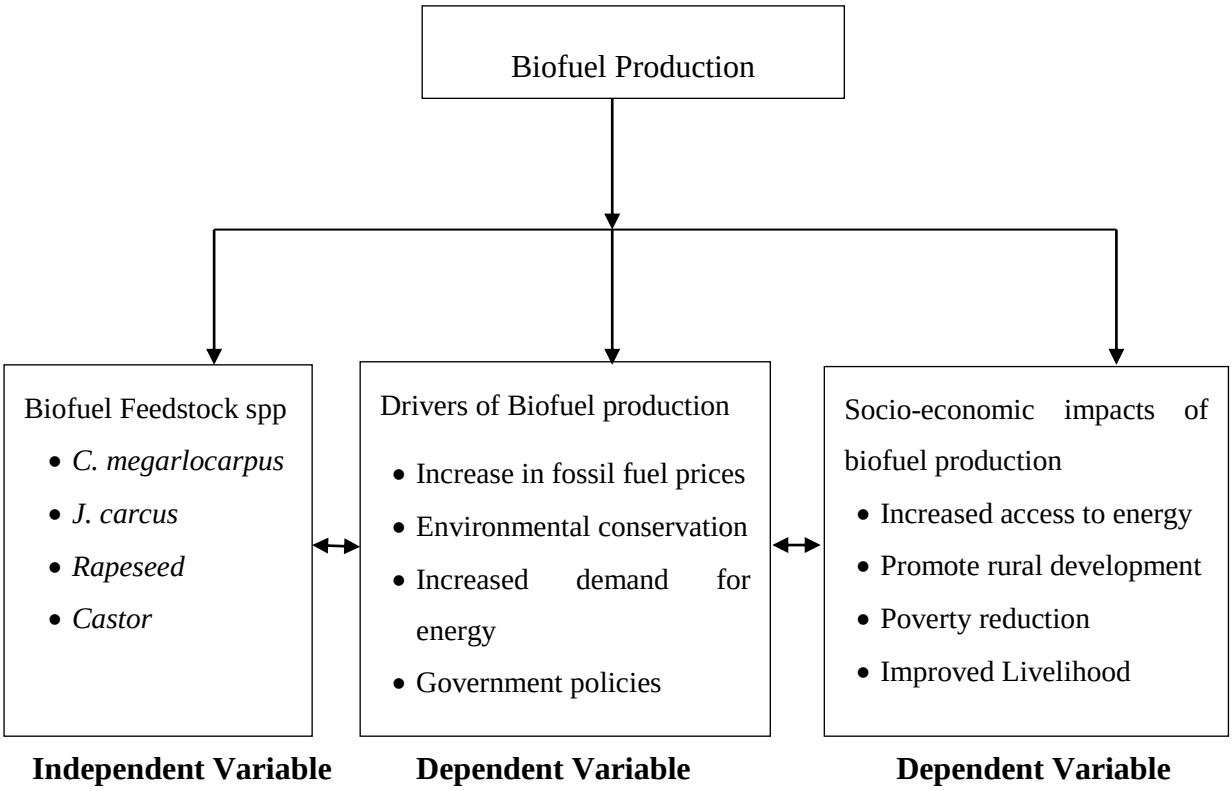


Figure 2.3: Conceptual Framework

The conceptual framework shows the study variables. The dynamics of biofuel production studied are the biofuel species, the drivers of biofuel production and the social-economic impacts of biofuel production. Biofuel species being promoted in the region could serve as an essential livelihood diversification strategy and possibly enable rural households to reduce poverty. The diversity of the species ensures that different farmers provide different species whose costs of production and income room the biofuels vary.

The drivers of biofuels include the demand for biofuels that may be attributed to oil values, energy safety anxieties, and worldwide climate alteration. Consequently, biofuel projects and biofuels government policies and development plans are some other possible drivers of biofuels. Bio petroleum manufacture has the potential to offer farmers with a long-term source of revenue as well as a ready supply of employment, particularly for the youth. It can also be a basis of local infrastructure and development improvements. Biofuel production could develop farmers' livelihoods by meeting community energy needs as well.

CHAPTER THREE: STUDY AREA AND METHODOLOGY

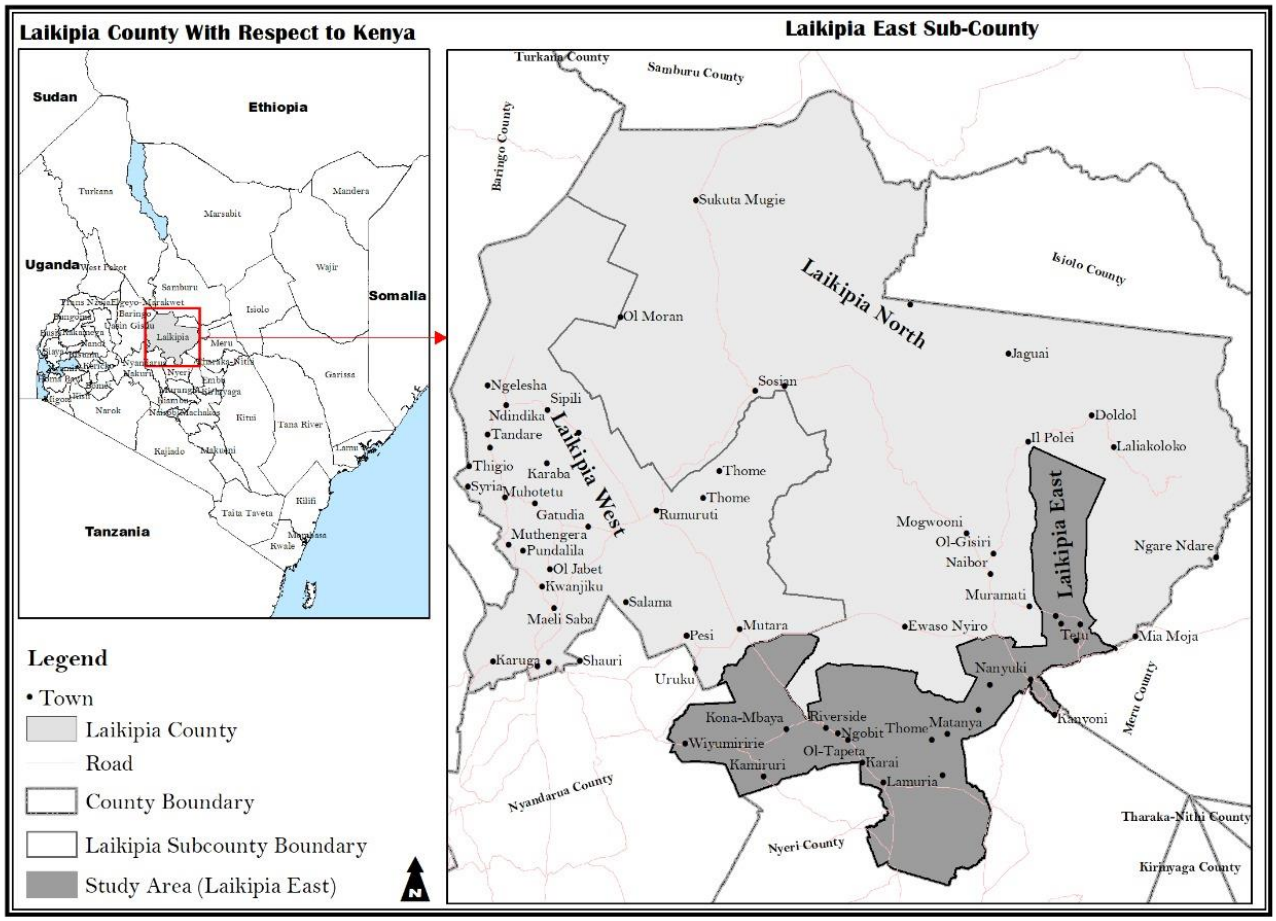
Study Area

3.1 Introduction

The section presents the research zone. The study area is described through its administrative boundaries, demographics, climate and vegetation.

3.2 Location

The research was conducted in Laikipia East sub-County which is one of the sub-Counties in Laikipia County in Kenya (figure 3.4)



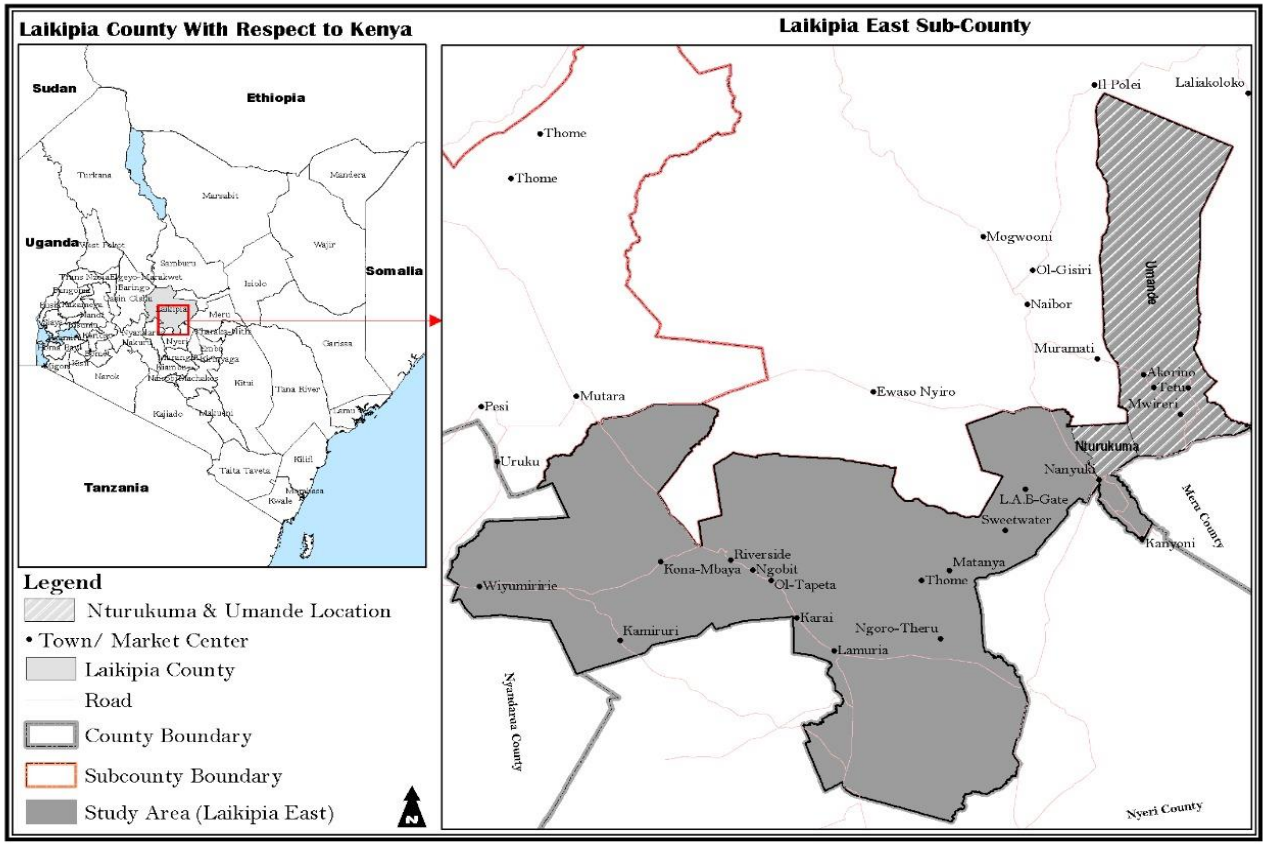


Figure 3.4: Location of Study Area in Laikipia County, Kenya

Source: Researcher 2021

Laikipia County is surrounded on the north by Samburu County, the north east by Isiolo County, the east by Meru County, the south east by Nyeri County, the south west by Nyandarua County and Nakuru County, and the west by Baringo County. Laikipia is divided into five administrative sub-Counties: East Laikipia, North Laikipia, Central Laikipia, West Laikipia, and Nyahururu.

3.3 Demographics

As per the 2009 Countrywide Census, the county has a populace of 399,227 people, with males constituting 49.8 percent and females constituting 50.2 percent. The Kikuyus and Maasai ethnic groups make up the majority of the County's people, which come from a variety of ethnic backgrounds.

There are a variety of religions in Laikipia County, although Christian and Muslim are the most common. Tourism and agriculture, particularly grain crops, livestock, and greenhouse horticulture, are the main sources of revenue in the county.

Table 3.3: Demographics- population and households in Laikipia East sub-County

	Male	**Female**	**Total**	**House holds**	**km²**
Laikipia East sub-County	56,313	56,970	113,283	31, 010	9,462
Ngobit **Sub-locations** Withare, Mutaro, Wiyumire, Njoguini, Kariguni, Nyambogichi Muhonia, Wamura and Ruai,	11,947	11,889	23,836	6, 544	271.20
Tigithi Lamuria and Matanya	13,584	13,369	26,953	5,892	562.00
Thingithu Thingithu and Marura	9,707	10,362	20,069	5,796	103.50
Nanyuki Ntukuruma, Likii and Majengo	12,943	13,324	26,267	8,349	36.00

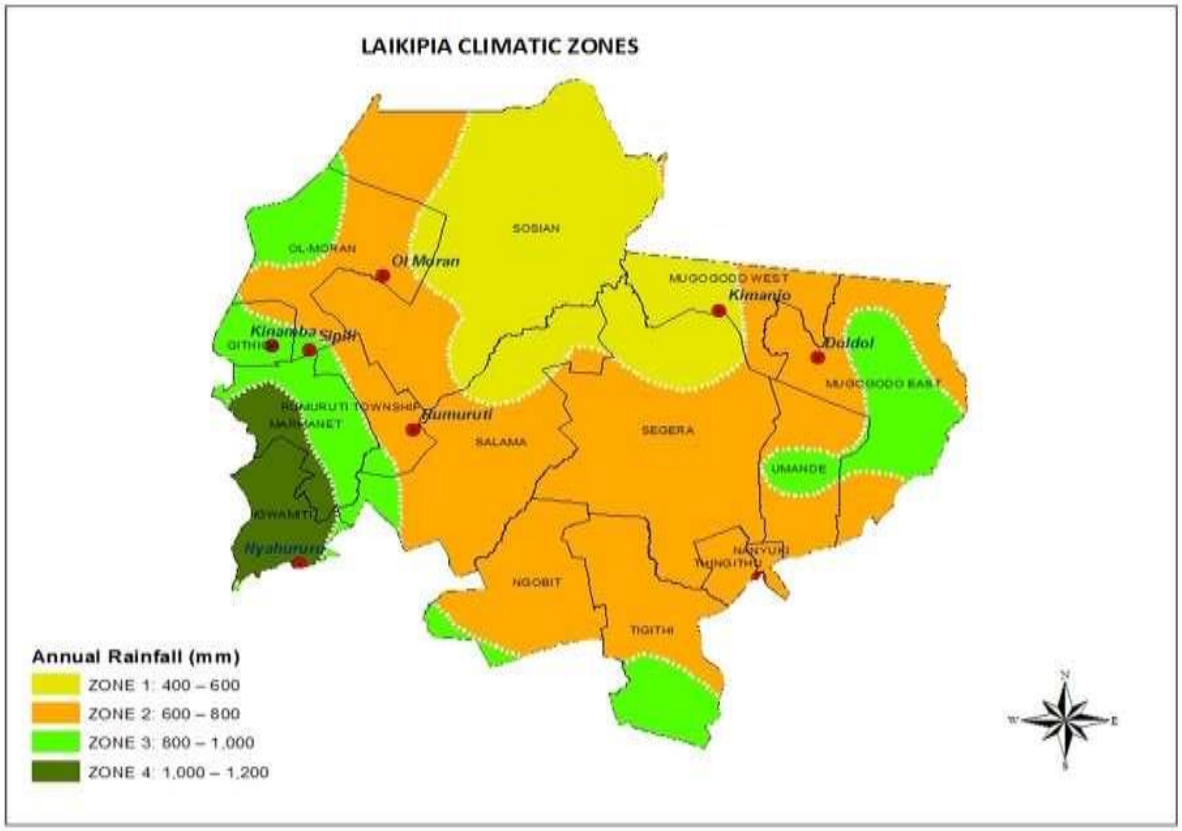
Umande Umande, Kalalu and Nyariginu	8,132	8,026	16,158	4,429	289.10

Source: *KNBS 2019*

3.4 Climate

3.4.1 The altitude

The County's elevation varies from 1,500 meters overhead sea level in the Ewaso Nyiro valley in the north to 2,611 meters above sea level in the areas surrounding Marmanet forest in the south. In some regions of the county, such as Mukogodo and Ol Daiga Forests in the eastern half, the height appears to be quite high, reaching up to 2,200 meters above sea level. There is a plateau bounded on the west by the Great Rift Valley, on the south by the Aberdares, and on the south east by the Mt. Kenya ridges, all of which have a significant influence on the county's overall climate.



Source; County Government of Laikipia, 2018

Figure 3.5 Laikipia climatic Zones

3.4.2 Rainfall

Because of its altitude and location, the County receives relief rains. The yearly regular precipitation is amid 400mm and 750mm, with advanced yearly precipitation sums in the parts abutting Mt. Kenya's slopes and the Aberdare Ranges. The average yearly temperature is between 19 and 23 degrees Celsius. Table 3.4 presents the mean annual rainfall of Laikipia.

Table 3.4: Mean annual rainfall of selected locations in Laikipia County in Millimetres (mm) 2013-2019

Station	2013	2014	2015	2016	2017	2018	2019
Doldol	376.9	457.8	358.4	311.8	571.3	555.4	918.1
Rumuruti	1159.5	554.4	713.4	848.6	685	723.3	774.8
Nyahururu	1560.5	623.7	690.0	931.5	1316.5	951.6	1490
Nanyuki	804.6	292.1	623.0	642.7	614.3	755.4	1011.3
Lamuria	857.5	727.9	690.0	732.5	590.0	721.2	1347

Source: *Meteorological Department, Laikipia office, 2020*

3.5 Vegetation

The county has a diverse range of natural resources. These include, pasture, rangeland, woods, nature, rolling terrain, and streams. The high possible land accounts for around 20.5 percent of the total land area of the county, whereas the remaining 79.5 percent is low-yielding and thus unsuitable for agricultural cultivation. The main soil types found in the county include loam, sand, and clay. The majority of the plateau is covered in black cotton soil. The hillsides are characterized by brown to red soils and rocky soils. The county's agricultural production is hampered by periodic dry spells and uneven rainfall distribution. The county has 580 km^2 of gazetted forest, which includes both indigenous and plantation woods. Mukogodo and Rumuruti have indigenous woods that are now

endangered by invasion. Marmanet and Shamaneik are the most common plantation woodlands. Castor, jatropha, and croton are among the biofuel crops farmed in the area.

Methodology

3.6 Introduction

This section discusses the procedure utilized in the research. The section discusses the research design, the sample size and sampling technique, the instruments used to gather data, and the data processing.

3.7 Research Design

This research applied an evocative review research project to analyze the dynamics of biofuel production among smallholder farmers in Laikipia East sub-County Laikipia. The descriptive survey research method was used in this research since it aided the researcher in gathering information about the present occurrence and, when possible, creating valid conditions from the facts. The ideal survey design for gathering data, summarizing, presenting, and analyzing for clarification is the descriptive survey approach (Creswell & Clark, 2007). The research was conducted in Nanyuki, Laikipia East sub-county Laikipia County. The study targeted the 3000 smallholder farmers who supply biofuel feedstock to Ecofix Kenya and the 12 employees of EFK Group Laikipia.

3.8 Sampling and Sampling Technique

3.8.1 Sample Size

A sample is a part of the target populace that is representative (Nardi, 2018). This study employed sampling formulae by Yamane (1967) and sampling technique in the determination of appropriate study sample size.

The desired sample size was given by:

$$n = \frac{N}{1 + N(e)^2}$$

Where: -

n= likely sample size,

N= size of the target populace,

“e” precision level

Thus

n= 3000/{1+3000(0.1)^2}

n=3000/31

n=96.77

n=97

The sample size was therefore 97 small household farmers. Therefore from the list of the 3000 farmers, 97 were selected for the study.

3.8.2 Sampling

Sampling techniques are associated with reduced cost and greater accuracy of results. Systematic sampling was adopted in the study. Systematic sampling was used to select smallholder farmers from the locations where the biofuel crop is grown where 97 respondents were selected from the list of farmers supplying biofuel crop to EFK. The Ecofix Kenya farmers list was used to sample the farmers to be interviewed. The chiefs, sub-chiefs and village elders were also used to identify the farmers in their localities. Out of the 3000 farmers in the EFK list every 31st farmer was selected to answer the

questionnaire. All the 12 employees of EFK Group Laikipia and 4 Government officers were selected by census and interviewed.

3.9 Data Collection Instruments and Procedures

The information was calm with the usage of surveys, interviews and focused group discussions.

Questionnaire

The study used a questionnaire to obtain data from household farmers. The questionnaire was more suitable for the study as it reached a great number of persons, and allowed for comparability and easy to analyze the data. Questionnaires possess the feature of uniformity which facilitates analysis of the data gathered (Wright, 2005).

According to Csikszentmihalyi and Larson (2014), surveys are usually used to acquire relevant information for a research's defined specific aims. Questionnaires have the added benefit of allowing a large number of people to be contacted quickly and cheaply. The research targeted households involved in biofuel production. It utilized data of farmers registered by EFK to supply biofuel feedstock. There were 3000 farmers who supplied feedstock to the company. The questionnaire obtained quantitative data and was structured into sections A, B,C and D. Section A collected personal information, section B was on species used in biofuel production, section C was on the drivers of biofuel production and section D was social economic impacts of biofuel production. A questionnaire survey was done through face-to-face to achieve maximum interaction with the respondents and get quick and reliable responses. To achieve this, local enumerators were recruited and trained in data collection.

Key informant interviews

A consultation guide was applied in the collection of information from the key informants who included the employees from EFK Group Laikipia. Other key informants were local farmers selected based on the number of biofuel crops supplied to the company. Government officers were also interviewed. These are the Agriculture officer, NEMA officer, Ministry of Energy, and the local Chief. Interviews enable the researcher to collect more detailed information from a population with the knowledge. The interviews were conducted by the researcher where the 12 employees of EFK Group in Laikipia and key informants were interviewed. The interview guide collected qualitative data.

Focused Group Discussions

Focused group discussions were used where a group of 8 to 10 farmers from each sub-location was used to obtain more data on the dynamics of biofuel production. The farmers forming the groups were different from those issued with questionnaires.

3.10 Data Presentation and Analyses

Quantitative data was coded then entered into the computer using SPSS Version 20. Quantitative data were analyzed by use of descriptive statistics such as frequencies, and percentages. Qualitative data generated from open-ended questions and interviews were analyzed using content analysis. The qualitative data was organized and analyzed into themes, categories and patterns pertinent to the study. Inferential statistics was also used in the study. Analysis of variance (ANOVA) was used to test the hypothesis.

CHAPTER FOUR: FINDINGS AND DISCUSSION

4.1 Introduction

This section shows an examination of the information composed for the research. Quantitative and qualitative approaches have been used in the analysis. Figures such as bar graphs and tables have been used to present the findings. 97 questionnaires were issued to respondents, however 91 questionnaires were duly filled and returned.

4.2 Household Characteristics

The results disclose that many of the participants, 65.9% were household heads. Those who were not the household heads were requested to indicate their relationship with the household heads. From the findings, 48.4% of the 31 respondents who were not household heads were spouses, 32.3% were sons while 19.4% were daughters above the age of 18. Among the respondents, 60% were female and 40% were males.

Among the respondents, 31.9% were above 50 years, 29.7% were between 41-50, 20.9% were between 31-40 years, 13.2% were between 21-30 years, 4.4% were below 20 years as obtainable in Figure 4.6.

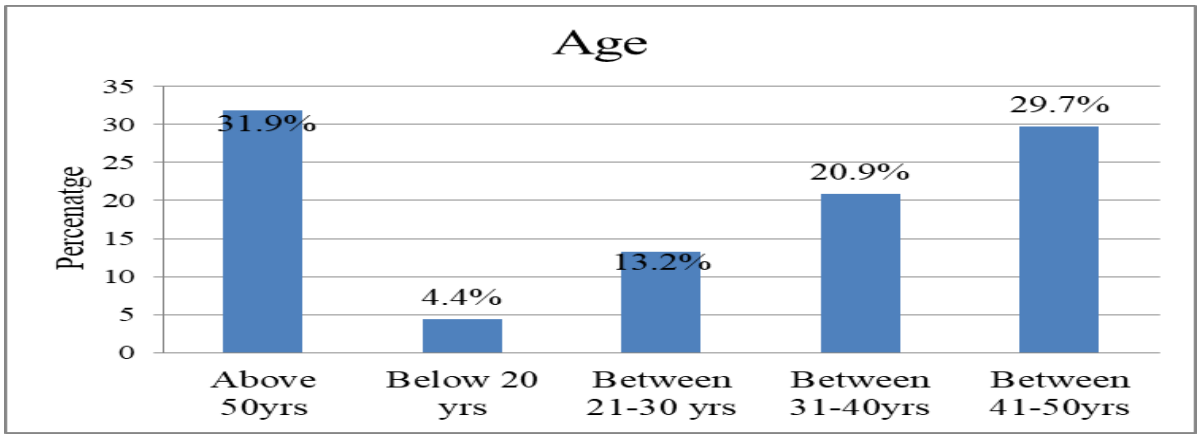


Figure 4.6: Respondents Age

From the findings, most of the participants (51.6%) had attained secondary level of education, 31.9% had basic education, 9.9% had no formal education, and 5.5% had Tertiary/College Level of education while 1.1% had degree level of education as shown in Table 4.5.

Table 4.5: Literacy Level

Literacy level	Frequency	Percentage
Degree Level	1	1.1
No formal education	9	9.9
Primary Level	29	31.9
Secondary Level	47	51.6
Tertiary / College Level	5	5.5
Total	91	100.0

From the findings, 84.6% obtained their income from farming, 8.8% from formal employment while 6.6% obtained their income from informal employment. This implies that the majority of the respondents obtained their income from farming. This is shown in Figure 4.7.

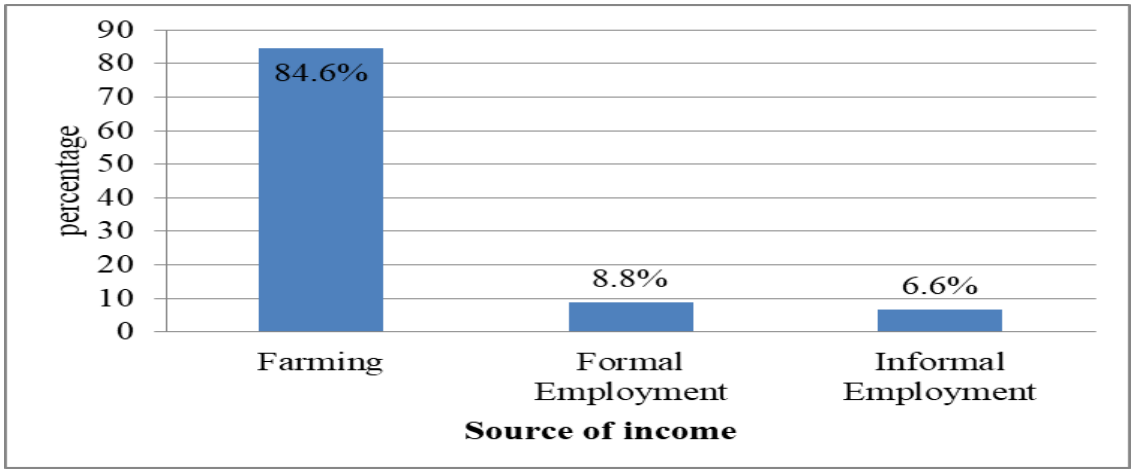


Figure 4.7: Source of income

The majority of the participants (86.6%) had 0-2 acres of land, 9.9% had 3-5 acres and 3.3% had over 5 acres of land as shown in Table 4.6.

Table 4.6: Adoption biofuel species in Acreage

Farm size	Frequency	Percentage
0-2 acres	79	86.8
3-5 acres	9	9.9
Over 5 acres	3	3.3
Total	91	100

4.3 Species Used in Biofuel production among smallholder farmers

All the 91 respondents indicated that they had one biofuel crop species, mainly *Croton megalocarpus*. *Croton spp* is commonly used in medicine, as an animal food and as a basis of fuelwood. Similar use of *Croton spp* has been documented in other areas like Naromoru by Self Help Centre in 2007(Takase *et al*, 2021). In this project, the farmers utilize *croton* seed waste as organic fertilizers and it helped the smallholder farmers to

improve crop production. Due to its success and affordability, farmers have adopted organic farming in their practice. This has assisted farmers not only to increase their yield but also to sell excess harvest in the local market thus improving their livelihood. Therefore, farmers have been able to produce additional income and savings. The project positively contributed towards increasing food safety at both the household and community levels.

It was revealed by the respondents that they grew the biofuel species for other reasons such as firewood, to get a good fence, to earn income, for shade, to beautify the compound, to feed chicken, aesthetics, to conserve the environment, for herbal medicine, due to encouragement by the government to protect the environment and to do their research. Consistent with the findings, Sage, (2013) argues that biofuels can deliver an answer to the twin glitches of deficiency and climate alteration.

All the respondents indicated that they collected the seedlings from other farms, from existing trees, bought seedlings from a tree nursery, buying from tree sellers, the seedlings grew by themselves indigenously and others were given by a friend. Similarly, in Malawi collection of seedlings from the farm is a common source of biofuel material as established by Boccanfuso and Savard (2012).

Most of the respondents (41.8%) used 1/8 of their farm to grow the biofuel species, 22% used half of the farm,18.7% used ¼ of the farm 15.4% used almost the whole farm while 2.2% used ¾ of the farm as revealed in Table 4.7.

Table 4.7: Approximate proportion of the land used in farming biofuel crops

Proportion of the land	Frequency	Percentage
1/8 of the farm	38	41.8
1/4 of the farm	17	18.7
1/2 of the farm	20	22.0
3/4 of the farm	2	2.2
Almost the whole farm	14	15.4
Total	91	100.0

The results presented in Table 4.7 show that 91.2% of the participants indicated that the biofuel crop is grown as a boundary, 6.6% indicated Woodlot and 2.2% indicated Strip farming between ridges or plots. The findings presented in table 4.8 below imply that the biofuel crop is grown as a boundary.

Table 4.8: Methods used in biofuel crops growing

Method	Frequency	Percentage
Boundary	83	91.2
Strip farming between ridges or plots	2	2.2
Woodlot	6	6.6
Total	91	100.0

The majority of the farmers (76.9%) had grown biofuel for over 5 years, 7.7% for the last 3 and 5years, 6.6% for the last 2 years and 1.1% for the last 4 years. The respondents noted that before growing the biofuel crops, the land was used for farming, settlement, bare land, subsistent farming and livestock rearing and settlement, just a fence and others

used the land for poultry farming. Many of the participants designated that there were no other biofuel species grown by their neigbours however a few indicated jatropha, Castor, and Cape chestnut biofuel species.

4.4 The Drivers of Biofuel Adoption among Smallholder Farmers

Table 4.9: Drivers of biofuel adoption among smallholder farmers

Drivers of biofuel adoption	Not at all	little extent	Moderate extent	great extent	Very great extent
Income			**%**		
Biofuels increase farm income	16.5	62.6	17.6	1.1	2.2
Biofuel increase household income	19.8	58.2	19.8	1.1	1.1
biofuel feedstocks have favourable prices	31.9	53.8	9.9	4.4	0
Biofuels improve the distribution of income	18.7	61.5	18.7	1.1	0
Livelihood			**%**		
It is an investment opportunity	28.6	51.6	15.4	3.3	1.1
Source of employment	27.5	54.9	14.2	2.2	1.1
Biofuels reduce poverty	28.6	56	14.3	1.1	0
Identification of best alternative crops	48.4	36.3	15.4	0	0
Biofuels have less related cost of production	6.6	18.7	61.5	26.4	0
Financial support	20.9	65.9	11	1.1	1.1

Drivers of biofuel adoption	Not at all	little extent	Moderate extent	great extent	Very great extent
Biofuels are environmental friendly	87.9	9.9	1.1	1.1	0
It is a sustainable investment	29.7	53.8	15.4	1.1	0
Market/ Demand	**%**				
Speedily rising demand for liquid biofuels such bioethanol and biodiesel	58.2	36.3	4.4	1.1	0
Feedstocks production and yield improvement	17.6	54.9	26.4	1.1	0
Land availability	**%**				
Availability of arable land	22	42.9	30.8	3.3	1.1
Available family land	24.2	41.8	29.7	3.3	1.1
Policies	**%**				
Tax exemptions and reliefs	69.2	16.5	8.8	4.4	1.1
Duty waivers	91.2	6.6	2.2	0	0
Government incentives	97.8	1.1	1.1	0	0
Environment	**%**				
To safeguard the biodiversity	5.5	9.9	28.6	25.3	30.8
The want to moderate climate change	2.2	6.6	15.4	56	19.8
Valid N (listwise	91				

The respondents indicated the following reasons behind their decisions to get involved in biofuel enterprises; for the purposes of getting extra income (85%), to get a good shade for the farm (78%), availability of market (58%), for airing in the household (43%), as a source of firewood (68%), for fencing purposes (72%) and source of fertilizers (74%). Similarly, GIZ/MOA (2013) found that biofuels are a good fence and are used for shade. They are also rich in nitrogen and phosphorus.

All the 91 (100%) respondents indicated that only one company by the name Ecofix Kenya is involved in biofuel processing in Laikipia. The respondents further indicated that they do farming (100%), livestock rearing and horticulture (96%), formal employment 8.8%) and businesses(6.6%) such as shop keeping. The respondents noted that they farm crops such as maize, beans and potatoes. From the findings, no respondents had abandoned other crops for biofuel farming. The respondents indicated that the tree fairs well with or without rainfall, with little rainfall the tree sheds off their leaves but with lots of rainfall the tree reproduces well, the more the rain the more harvests they get and that the tree is not affected by the seasons. Consistent with the findings, GIZ/MOA, (2013) revealed that Croton is fast-growing and can do well in difficult climatic conditions.

Many of the participants (67%) showed that there is no cattle rustling in the area. Some of the respondents (46%) believed that farmers abandoned livestock farming for the adoption of biofuel farming. The respondents (59%) indicated that the children help in picking the crop for livestock food and chicken feed. The crop is used to protect the soil from soil erosion and acts as a windbreaker and helps attract rainfall.

The findings are presented in Table 4.9 show that on income as the driver, the majority of the participants settled to a little degree that biofuels increase farm income as shown by (62.6%), biofuels improve the distribution of income (61.5%), biofuel increase household income (58.2%) and that biofuel feedstocks have favorable prices (53.8%).

On livelihood as a driver of biofuel farming, many of the participants agreed to a great degree that biofuels have a less related cost of production (61.5%). The majority of the respondents agreed to a little extent that it is an investment opportunity (51.6%), offer financial support (65.9%), source of employment (54.9%), biofuels reduce poverty (56%) and that it is a sustainable investment (53.8%). Similarly, a study by Koh and Ghazoul, (2018) established that biofuel production results in higher employment rates and wages. The respondent disagreed with being in biofuel farming as a result of the identification of best alternative crops (48.4%) or biofuels being environmentally friendly (87.9%).

On market/ demand as the driver, many of the respondents decided to a little degree on feedstocks production and yield improvement (54.9%) and disagreed on speedily rising demand for liquid biofuels such bioethanol and biodiesel (58.2%).

On land availability, the respondents agreed to a little extent on the availability of arable land (69.2%) and available family land (41.8%).

On policies as the driver for biofuel farming, the majority of the respondents disagreed on tax exemptions and reliefs (69.2%), duty waivers (91.2%), and on government incentives (97.8%).

On the environment, the majority of the respondents agreed to a great extent that they engaged in biofuel farming due to the desire to moderate climate change (56%) and others to safeguard the biodiversity (25.3%). Consistent with the results GIZ/MOA (2013) reveal

that biofuels have huge benefits on the air quality and significantly lower emissions from the exhaust as compared to other emissions from other sources and thus useful in climate change mitigation.

4.5 Socio-Economic Impacts of Biofuel production

Table 4.10: Socio-economic impacts of the biofuel industry

Socio-economic impacts	Not at all	little extent	Moderate extent	great extent	Very great extent
	%				
Biofuel industry has created employment for me	30.8	57.1	7.7	2.2	2.2
Farming of biofuel crops have become my source of income	25.3	67	4.4	.1	2.2
Biofuel industry has increased food production in the area	26.4	57.1	14.3	2.2	0
Farming of biofuel crops has reduced poverty	26.4	62.6	11	0	0
Biofuel industry has brought infrastructure development in this area	86.9	7.7	5.5	0	0
Biofuel industry has contributed to establishment of social amenities in the area	81.3	13.2	5.5	0	0

Socio-economic impacts	Not at all	little extent	Moderate extent	great extent	Very great extent
Many people earn their living from the biofuel industry	25.2	61.5	13.2	0	0
Farming biofuel crops has increased my savings	33	57.1	7.7	2.2	0
Biofuel farming has led to development of infrastructure	90.1	8.8	1.1	0	0
The social-well-being has improved due to biofuel farming	25.3	67	5.5	2.2	0
Valid N (listwise)	91				

From the results, the respondents agreed that the biofuel production has helped to make some income, it creates employment for some people since some become agents, raises their living standards to a very small extent, it has helped the respondent get firewood to use in the household, it has helped in enhancing fresh air in the environment and it has provided a great climate in the area. Similarly, Groom *et al.* (2015) found that biofuels reduce the amount of gas emissions produced preventing air pollution.

The respondents indicated that biofuel farming has reduced poverty though to a very little extent. They further indicated that the low prices have prevented much effect of biofuel farming on poverty.

The findings demonstrate that many of the participants (97.4%) agreed that biofuel does not contest with the area owed for food production while 2.6% were of the opinion that biofuel competes with the area allocated for food production. The findings further reveal that almost all the respondents (99.5%) indicated that biofuel does not compete with the area allocated for livestock production. Inconsistent with the findings, the Food and Agricultural Organization (2011) recorded that biofuel are always in competition with other crops for land and water.

Many of the participants decided to the little degree that the biofuel industry has increased food production in the area (57.1%), the biofuel industry has created employment for them (57.1%). Similar findings where biofuel helped in creating employment were recorded by De la Torre Ugarte *et al.* (2017). Other impacts include, farming of biofuel crops have become their source of income (67%), many people earn their living from the biofuel industry (61.5%), the social-well-being has improved due to biofuel (67%), farming of biofuel crops has reduced poverty (62.6%) and that farming biofuel crops has increased their savings (57.1%). Similarly, Koh and Ghazoul, (2018) recorded that biofuel arming has improved the livelihoods of the farmers by increasing their income thus reducing poverty levels. The respondents did not agree that the biofuel industry has contributed to the establishment of social amenities in the area (81.3%), the biofuel industry has brought infrastructure development in this area (86.9%) and that biofuel farming has led to the development of infrastructure (90.1%).

The respondents provided further information that the tree has a lot of many other advantages although the selling prices are very low. They acknowledged that the crop is a good source of livestock feed, the trees cost of production is good and is valuable and has

helped children in the area for example some sell to make money for pens. Others mentioned that croton farming activities involve the children hence most adults ignore the collection of the Croton seeds for sale. The respondents indicated that an increase in the price could motivate farmers. They suggested that more research be done on biofuel farming and the government should make effort to encourage farmers to grow the crop. The respondents suggested that croton be made a cash crop and the prices should be increased. Sufficient information on the importance of croton would encourage farmers to participate in biofuel production. The industries have not informed people on the importance of farming biofuel feedstocks and there is need for the industry to interact more with farmers to enhance biofuel crops production. The respondents indicated that the variety of croton available grows very slowly and takes a longer time to grow and recommended that scientists should come up with a variety that takes a shorter period to improve production. They also noted that buying agents are sometimes not available to purchase the seeds. They therefore suggested that they should always be available and interact closely with the farmers.

4.6 Hypothesis testing

Table 4.11: ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11.241	21	.535	4.852	.000
Within Groups	7.612	69	.110		
Total	18.853	90			

From the ANOVA table the p-value is less than the significance level, (0.000<0.05). Thus we reject the null hypothesis and conclude that there is a statistically significant socio-economic impact of biofuel production among smallholder farmers in Laikipia East sub-County, Laikipia County.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The section presents a summary of the research findings and the conclusions made. The section also presents policy recommendations and suggestions for further studies.

5.2 Summary of Findings

The research focused on the dynamics of the biofuel production among smallholder farmers in Laikipia East Sub County Laikipia.

The study found that only *croton spp* biofuel crop species are grown in Laikipia East Sub County Laikipia. The biofuel crop species are grown for firewood, as a fence, income, shade, for beautification of the compound, makes chicken feeds, for aesthetics, to conserve the environment and for herbal medicine. The farmers collect the seedlings either from other farms, from existing trees or buy from seedling vendors.

Most of the farmers use approximately an eighth of their farm to grow the biofuel species. *Croton spp* is largely grown as a boundary tree. The study found that majority of the farmers had grown the crop for over 5 years. Before growing the biofuel crops, the land was used for farming, settlement, subsistent farming and livestock rearing and settlement, and others used the land for poultry farming.

The study further found that the biofuel enterprises were; for the purposes of getting additional income, to get a good shade for the farm, availability of market, for airing in the household, as a source of firewood, for fencing purposes and source of fertilizers. The study identified only one company, Ecofix Kenya, involved in biofuel production.

The study found that the farmers are also involved in livestock rearing and horticulture, formal employment and businesses such as shop keeping. They also grow other farm crops such as maize, beans and potatoes but did not abandon other crops for the purposes of biofuel farming. The findings revealed that biofuel farming requires high rainfall but is adaptive when the rainfall is low.

The study revealed that biofuels increase farm income to a little extent. The study found that biofuels have a less related cost of production but cannot be said to be a sustainable investment. Being in biofuel farming is not as a result of the identification of the best alternative crops. The study revealed that market/ demand, land availability and policies were not key drivers for biofuel farming. There are no tax exemptions and reliefs, duty waivers, or government incentives in the industry.

The study found that environment conservation was a key driver of biofuel crop farming. The farmers are involved in biofuel farming due to the want to moderate climate change and safeguard biodiversity.

The study found that the biofuel production has helped to make some income. It creates a few employment opportunities for some people since some become agents and raises their living standards to a small extent. The production has helped the respondent get firewood to use in the household, it has helped in enhancing fresh air in the environment and it has provided a great climate in the area. Biofuel farming has reduced poverty though to a very little extent since the prices are very low. The study also found that biofuel crop farming does not contest with the area owed for food production or for livestock production.

The study found that the biofuel production has little effect on food production in the area, on the social-well-being and their savings. Besides, the study found that the biofuel

production has not contributed to the establishment of social amenities in the area as neither has it brought infrastructure development in this area.

The respondents provided further information that the tree has a lot of many other advantages although the selling prices are very low. They acknowledged that the crop is a good source of livestock feed, the trees cost of production is good and is valuable. Others mentioned that croton farming activities involve the children hence most adults ignore the collection of the Croton seeds for sale.

5.3 Conclusions

The research acknowledges that *croton spp* is the common biofuel crop species grown in Laikipia East sub-County Laikipia and largely grown as a boundary crop. The species is grown for firewood, fence, income, shade, beautify the compound, chicken feed and for environmental conservation. The seedlings are obtained from other farms, from existing trees or bought from the seedling vendors. Only Ecofix Kenya Company is involved in biofuel crops in Laikipia East sub-County Laikipia.

The main reasons for biofuel adoption among smallholder farmers in Laikipia East Sub County Laikipia are; to get firewood, extra income, and good shade for the farm, availability of market, airing in the household and for fencing purposes. The farmers in the area are also involved in livestock rearing and horticulture, formal employment and businesses such as shopkeeping.

Market or demand, land availability and policies were noted as not key drivers for biofuel farming among smallholder farmers in Laikipia East sub-County Laikipia. There are no tax exemptions and reliefs, duty waivers or government incentives in the industry. Environment conservation was a key driver of biofuel crop farming among smallholder

farmers in Laikipia East sub-County Laikipia. The farmers are involved in biofuel farming since they want to moderate climate change and to safeguard biodiversity.

The biofuel production has significant social-economic impacts among smallholder farmers in Laikipia East sub-County Laikipia. Biofuel production has helped the farmers to make some income, it has created a few employment opportunities, it has helped to get firewood for the household, it has helped in enhancing fresh air in the environment and it has provided a great climate in the area.

The biofuel production has little impact on poverty reduction since the prices are very low. The production also has little effect on food production in the area, on the social-well-being and on their savings. In addition, the biofuel production has not contributed to the establishment of social amenities in the area as neither has it brought infrastructure development in this area.

5.4 Recommendations

The research made the following recommendations;

5.4.1 Recommendations for policymakers

The company, Ecofix Kenya should consider offering favorable prices to the farmers to encourage more production of the biofuel crop which will ensure that the company has an adequate supply.

The government needs to promote croton production for biofuel and environmental conservation.

More research needs to be done on the crop and other biofuel crops that are suitable for the area's climatic conditions. The research should seek to come up with biofuel crops

variety that takes a shorter time to grow and how best to increase the yields of the existing breed.

Extension officers either from the government or the company should be used to reach out to the farmers to provide information and educate the farmers on the biofuel crop farming. This would increase the production and at the same time increase the farmers' income which will be a suitable strategy to reduce poverty in the area.

The Ecofix Kenya Company should take corporate social responsibilities in the area by bringing development in the area. This may include building social amenities for the residents in the area such as social halls, health facilities or even schools.

The government should encourage the growth of biofuel crops since its one of the sources of energy and a way that has the potential of reducing poverty among households. The government should provide incentives and facilitate other investors who may be interested in the biofuel production by ensuring that the policies and laws are conducive for business.

5.4.2 Recommendations for further studies

The research has revealed that biofuel production has some social-economic benefits among the smallholder farmers in Laikipia East sub, County Laikipia. However, most of the farmers have not adopted biofuel crop farming with the seriousness deserved to bring out its potential. Thus, additional studies should be done to establish the challenges in the biofuel crop farming and the factor that influence the biofuel crop farming in the Laikipia East sub-County.

The study has also revealed that only the Ecofix Kenya Company is operating in Laikipia East sub-County Laikipia. Additional studies should be conducted to discover the issues that hinder investment in the biofuel industry in the area.

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APPENDIX I: QUESTIONNAIRE FOR THE FARMERS

SECTION A: PERSONAL INFORMATION

1. Respondent gender

   Male ☐

   Female ☐

2. Respondent Age Brackets

   Below 20 yrs. ☐

   Between 21-30 yrs. ☐

   Between 31-40yrs ☐

   Between 41-50yrs ☐

   Above 50yrs ☐

3. Respondent Education Level Attained

   No formal education [ ] Primary Level [ ]

   Secondary Level [ ] Tertiary / Collage Level [ ]

   Degree Level [ ] Others ……..

SECTION B: SPECIES USED IN BIOFUEL INDUSTRY AMONG SMALLHOLDER

4. What bio fuel crops species do you grow?

   .....

   .....

   .....

   .....

5. Why do you grow the mentioned species?

……

……

……

……..

6. What other bio fuel crops species are grown in your neighborhood?

   ……

   ……

   …….

SECTION C: THE DRIVERS OF BIOFUEL ADOPTION AMONG SMALLHOLDER FARMERS

7. To what degree to do you agree with the below declarations on the drivers of biofuel adoption among smallholder farmers in Laikipia East sub County Laikipia. Kindly indicate as appropriate with 1=Not at all 2=little extent 3=Moderate extent 4=great extent 5=Very great extent

Statements on drivers of biofuel	1	2	3	4	5
INCOME					
Biofuels increase farm income					
Biofuel increase household income					
biofuel feedstocks have favourable prices					
Biofuels improve the distribution of income					
Livelihood					
It is an investment opportunity					
Source of employment					
Biofuels reduce poverty					
Identification of best alternative crops					
Biofuels have less related cost of production					
Financial support					
Biofuels are environmental friendly					
It is a sustainable investment					
Market/ Demand					
Speedily rising demand for liquid biofuels such bioethanol and biodiesel					
Feedstocks production and yield improvement					
Land availability					
Availability of arable land					

Available family land					
Policies					
Tax exemptions and reliefs					
Duty waivers					
Government incentives					
Environment					
To safeguard the biodiversity					
The want to moderate climate change					

8. What are other drivers of biofuel adoption among smallholder farmers in Laikipia East sub County Laikipia?

   .....

   .....

   .....

SECTION D: SOCIO-ECONOMIC IMPACTS OF BIOFUEL INDUSTRY

9. Does biofuel industry Socio-economic impacts among smallholder farmers in Laikipia East sub County Laikipia?

   Yes ( )

   No ( )

10. To what extent to do you agree with the below statements on socio-economic impacts of biofuel industry among smallholder farmers in Laikipia East sub County Laikipia. Kindly indicate as appropriate with 1=Not at all 2=little extent 3=Moderate extent 4=great extent 5=Very great extent

Statements on social economic impact on biofuel industry	1	2	3	4	5
Biofuel industry has created employment for me					
Farming of biofuel crops have become my source of income					
Biofuel industry has increased food production in the area					
Farming of biofuel crops has reduced poverty					
Biofuel industry has brought infrastructure development in this area					

Biofuel industry has contributed to establishment of social amenities in the area					
Many people earn their living from the biofuel industry					
Farming biofuel crops has increased my savings					
Biofuel farming has led to development of infrastructure					
The social-well-being has improved due to biofuel farming					

Thank you

APPENDIX II: INTERVIEW SCHEDULE FOR KEY INFORMANTS

1. What are the different species used in biofuel industry among smallholder farmers in Laikipia East sub County Laikipia?
2. What are the drivers of biofuel adoption among smallholder farmers in Laikipia East sub County Laikipia?
3. What are the socio-economic impacts of biofuel industry among smallholder farmers in Laikipia East sub County Laikipia?
4. What is the effect of biofuel industry on the employment among smallholder farmers in Laikipia East sub County Laikipia?
5. How does biofuel industry influence the income levels among smallholder farmers in Laikipia East sub County Laikipia?
6. What the influence of biofuel industry on food production among smallholder farmers in Laikipia East sub County Laikipia?

APPENDIX III: FOCUSED GROUP DISCUSSION

1. Species used in biofuel industry among smallholder farmers in Laikipia East sub County.
2. Drivers of biofuel adoption among smallholder farmers in Laikipia East sub County.
3. Socio-economic impacts of biofuel industry among smallholder farmers in Laikipia East sub County.
4. Effect of biofuel industry on employment, income levels and food production among smallholder farmers in Laikipia East sub County.