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(CASELAP)

ASSESSMENT OF SUSTAINABLE CHARCOAL PRODUCTION IN KENYAN

DRYLANDS: A CASE OF MARIGAT SUB COUNTY

By

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DECLARATION

This thesis is my original work and has not been submitted in any other university for a degree or any other institution of higher learning for examination

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DEDICATION

I dedicate this work to my dad, I know you are resting in Heaven. Your foundation instilled in us and the vision for the family culminates the fruits of this work.

ABSTRACT

Charcoal is an important source of cooking energy for many households in Kenya. However, overharvesting of trees and use of inefficient technologies contributes to unsustainable charcoal production. This problem is compounded by increased preferences and demand for charcoal from specific indigenous trees resulting to immense pressure on Kenyan drylands. However, recent studies have shown that *Prosopis juliflora* produces high calorific value charcoal and can be used as a management tool for its invasiveness. Using producers from Marigat sub county, this study sought to assess sustainability of charcoal production in Kenyan drylands. Specifically, the study aimed to; i) characterize charcoal production systems in Marigat sub county, ii) assess the environmental impact of charcoal production systems in Marigat sub county, and iii) evaluate how the existing policy and institutional framework support sustainable charcoal production systems in Marigat sub county. To accomplish these objectives, the study used a random sample of 332 charcoal producer households. Findings indicated that the dominant charcoal production system encompasses 100% of producers using traditional earth kiln and 70% practice clear harvesting encouraging mass utilization of the invasive *Prosopis juliflora*. Therefore, these findings could help to design effective production systems that incorporates both the charcoal sector policies and regulations as well as assist to address the menace of the invasive *prosopis juliflora* on the environment. In addition, the policies reviewed recognize charcoal as an important source of energy and are geared towards sustainable charcoal production. However, a review of the Energy Act, 2006 will help the Energy regulatory Commission (ERC) to establish codes that will be fundamental in charcoal certification hence protecting tree species facing extinction and encourage utilization of charcoal from *Prosopis juliflora*.

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ABBREVIATIONS

ASALS	Arid and semi-arid lands
CE	Choice Experiment
CIDP	County Integrated development Plan
CPAs	Charcoal Producer Associations
CS	Cabinet Secretary
EMCA	Environmental Management and Coordination Act
ERC	Energy Regulatory Commission
FAO	Food and Agriculture Organization
FGD	Focused Group Discussion
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft fuer Internationale Zusammenarbeit
GoK	Government of Kenya
ICRAF	International Centre for Research in Agroforestry
KEBS	Kenya Bureau of Standards
KEFRI	Kenya Forestry Research Institute
KES	Kenya Shillings
KFS	Kenya Forest Service
KPHC	Kenya Population and Housing census
LPG	Liquefied Petroleum Gas
MENR	Ministry of Environment & Natural resources
MSTQ	Measures Standards Testing and Quality Assurance
NEMA	National Environment Management Authority
ODK	Open Data Kit
SPSS	Statistical Package for Social Sciences
SSA	Sub Saharan Africa
WTP	Willingness to Pay

CHAPTER ONE: INTRODUCTION

1.1 Background

Globally, bioenergy (traditional biomass included) accounted for 10.4% in the total primary energy supply in 2014 (FAO, 2016). Compared to other forms of energy, bioenergy contributes to over 60% of the total energy used in sub-Saharan Africa (IEA, 2014). In Africa alone, charcoal is a major source of energy with about 90% of urban households using it for cooking and heating (Schure, 2013). Although other renewable energy sources such as hydro, wind, solar, geothermal and modern bioenergy exist, their use only accounted for less than 2% of SSA energy mix (IEA, 2014).

Charcoal as fuel is a product of biomass carbonization. Biomass for charcoal production in Africa is mainly obtained from naturally regenerated forests and woodlands to pave the way for agricultural activities (Hofsted *et al.*, 2009). However in Rwanda, biomass from trees planted in private plantations are used for charcoal production. Drylands in Kenya provide over 75% of hardwood used for charcoal production (Iiyama *et al.*, 2014). However, clearance of both forest and woodlands is hastened with predominant use of inefficient kilns with low conversion rate of 8-20% (Chidumayo and Gumbo, 2014).

Charcoal production systems encompasses type of trees harvesting, the technology used and scale of production. Charcoal is a main product of a tree when the wood harvested is solely used for charcoal production. On the other hand, charcoal can also be a by product of the harvested tree that has been used primarily for other functions such as production of timber, poles etc thus prompting the owner to carbonize tree stump and other residues.

In sub Saharan Africa, charcoal is mainly produced from above ground tree biomass. The process involves felling of the whole or part of the tree for carbonization.

There are different types of kilns used for charcoal production. They include, traditional kilns, casamance, brick kiln and metal kilns. Traditional kilns are commonly used in SSA and they consist of two types, the earth mound kiln and the pit kiln. Similarly, in Kenya, 99% of charcoal producers use traditional earth mound kiln (Mutimba and Barasa, 2005). The earth mound kiln is constructed by piling up the wood with leaves and small twigs and soil whereas the pit kiln involves digging a hole or trench, then arranging the wood covered with green leaves or metal sheets and soil to prevent complete combustion during carbonization. Improved technologies such as casamance, brick kiln, metal kiln have more ventilation channels incorporating sufficient air circulation during carbonization resulting to higher wood-charcoal conversion. In addition, the mobility factor of the metal kiln, is an added advantage that cuts cost of transporting wood to the stationary kilns. The conversion rate of dry biomass for the kilns varies from one kiln to another (Oduor *et al.*, 2006).

Charcoal production can be classified into two types, small-scale and large scale. Small-scale production is labour intensive. It involves the growing of fuel, harvesting of wood, drying and preparation of wood for carbonization, actual carbonization and lastly, sorting charcoal for sale and transportation. On the other hand, large scale charcoal production also known as industrial charcoal production entails research, development of design and dissemination of knowledge on the suitability of the technology used. In addition, quality criteria are enhanced with emphasis on environmental protection.

The impact of charcoal production on the environment occurs at every stage from production to consumption. However, it differs with the intensity of production, type of technology used and ecological condition. For instance, the tropical savannahs and woodlands are the most degraded ecosystems (MacFarlane *et al.*, 2015). Degradation is as a result of excessive human use such as wood harvesting and grazing impacting the vegetation cover and diversity. Similarly, Kiruki *et al.*, (2017) agrees that different land uses such as charcoal production have varying effect on the composition, structure and vegetation diversity of woodlands.

Charcoal production contributes to forest degradation, for instance, selective harvesting targeting slow-growing hardwood species alters the composition and physiognomy of the forest and woodlands (Iiyama *et al.*, 2015; Ndegwa *et al.*, 2016). Woodland degradation impacts forest goods such as resin, honey, bush meat, medicine and other services such as erosion control, carbon sequestration and biodiversity contributing to depletion of these resources and a threat to sustainability (Iiyama *et al.*, 2015).

Loss of biodiversity as a result of charcoal production may occur through different ways. For instance harvesting of old-growth trees may result in fast growing secondary species replacing the slow-growing indigenous trees. The extent of the disturbance as a result of tree harvesting for charcoal production influences plant evolutionary characteristics such as timing of reproduction, seed size and seed germination. Further, the ecosystem and population structure of these species is disrupted with notable change in characteristics such as species diversity, nutrient output and biomass harvested.

Woodlands are important carbon sinks in the environment. However, charcoal production in these woodlands remains unsustainable (Zulu and Richardson, 2013). Recent studies have revealed that charcoal production in woodlands contributes to greenhouse gases (GHS) emission on the

environment (Bailis *et al.*, 2015). The main greenhouse gases emitted from charcoal production are methane and carbon dioxide (Kammen and Lew, 2005). Despite Africa contributing very minimal in global emission, two-thirds of her emission are as result of greenhouse gases from charcoal production. Further studies have also revealed that clearance of woodlands resulted to reduction of aboveground carbon stock (Kalaba *et al.*, 2013).

Kenya's charcoal sector is governed by a set of policies and institutional frameworks. For instance, various policies and legislations manage, guide, support and regulate the sector from production to consumption (Sola *et al.*, 2019). These policies and institutional frameworks are embedded within different sectors such as forestry, energy and the environment. They include, the energy policy 2004, the Forest policy 2014, the environment policy 2013. In Marigat sub county, the passing of the Baringo Sustainable Charcoal Production Bill 2014 also aims to supplement the provisions of charcoal rules 2009 at the county level.

1.2 Statement of the Research Problem

Marigat sub county is classified as one of the dryland areas in Kenya and charcoal production is one of the main livelihood sources for the people in the area (Ndegwa *et al.*, 2019). According to Mutiti (2010), the dominant tree species found in these dryland areas are *Acacia* spp. and *Commiphora* spp. Therefore, charcoal production has always been through the use of *Acacia* spp. The high demand for charcoal from these slow-growing hardwood tree species has led to their overexploitation and is a significant threat to biodiversity and if unchecked may lead to permanent physiognomy changes in the environment. Charcoal obtained from specific indigenous tree species in dryland areas is dense and of high calorific value, but these trees take longer time to mature than softwood trees (Chidumayo and Gumbo, 2013). In 1983, *Prosopis juliflora* was introduced in Marigat sub county to mitigate desertification in the drylands (Kariuki, 1993; Pimentel *et al.*,

2000). The plant was preferred due to its resilient nature in dry conditions and fast maturity. However, its invasiveness characteristic is a menace to biodiversity, grazing land and cropland. Although the national wildlife conservation and management policy 2017 classifies *P.juliflora* as invasive species threatening biodiversity and nature's contribution to people, recent studies have also shown that even though charcoal from *P.juliflora* is lighter than *Acacia* spp, it has high calorific value making it suitable not only for charcoal production but also for managing its invasiveness. It is against this background that the study seeks to assess the sustainability of charcoal production and good environmental management options for the invasive species in Marigat sub county.

1.3 Research Questions

The following main research question guided the study: how are charcoal production system impacting the environment in Kenyan drylands?

The sub-questions of the study were:

1. What are the characteristics of charcoal production systems in Marigat sub-county?
2. What are the environmental impacts of the charcoal productions systems in Marigat sub county?
3. How do the existing policy and institutional framework support a sustainable charcoal production system in Marigat sub county?

1.4 Research Objectives

The central research objective of the study was to assess how charcoal production system impact the environment in Kenyan drylands.

The specific objectives for the study were:

1. To characterize charcoal production systems in Marigat sub-county.
2. To assess the environmental impacts of charcoal production systems in Marigat sub county.
3. To evaluate how the existing policy and institutional framework support a sustainable charcoal production system in Marigat sub county.

1.5 Justification of the Study

Although charcoal production is detrimental to the environment it is also an important source of energy for a majority of households in Kenya. *Prosopis juliflora* invasiveness threatens biodiversity and livelihoods of people in Marigat sub county. However, recent studies have shown that charcoal from *P.juliflora* has high calorific value making it suitable for charcoal production. Therefore, findings from the study will provide a basis i) to inform policymakers on making charcoal production sustainable in the drylands ii) to inform charcoal production as a tool for managing invasive species.

1.6 Limitations of the Study

The study selected one of the drylands county where *Prosopis juliflora* is an invasive species. However, due to time and financial limitations the study only focused on the *P. juliflora* drylands more specifically Marigat sub county.

CHAPTER TWO: LITERATURE REVIEW

This chapter gives a detailed discussion of relevant literature on charcoal production and environmental impacts. Literature on policy framework influencing the charcoal sector has also been reviewed. For this study, the review is thematic and was mainly guided by the main objectives. Key sections covered are charcoal production and its impacts on the environment, the demand and utilization and governance aspect of charcoal in Kenya. Lastly, is an empirical review and summary of the chapter.

2.1 Charcoal Production and the Environment

Charcoal production activities involves identification of wood, harvesting, setting up of the kiln and the carbonization process and finally yield produced. Therefore, there is a close relationship on the impact on the environment and these activities. The relationship varies with the intensity of production, type of kiln used and the type of trees targeted for charcoal.

2.1.1 Charcoal Production and Technologies

Charcoal is the product of wood and wood material obtained from different parts of a tree such as branches and trunk that has undergone burning in a regulated amount of oxygen (Agbugba & Obi, 2013). Out of the total 3.7 billion m³ of wood extracted from forests globally, 50% was used as fuel or other forms of woodfuel with charcoal production accounting for 17% of this half (FAO, 2016a). Recent studies done in 2015 revealed Brazil as the leading charcoal producer globally (FAO, 2016d). In terms of volumes produced, Africa contributed to 62% of the global charcoal mostly done in the SSA (FAO, 2017). Continentally in the top ten list, Nigeria is the leading charcoal producer nation, followed by Ethiopia, Democratic Republic of Congo (DRC), Ghana, the United Republic of Tanzania and Madagascar in that order (FAO, 2016d). The DRC is one of the poorest countries in the world with the tropical forests covering approximately 130 million

hectares which is 60% of the Congo Basin (UNDP, 2011). Clearing of land for agricultural purposes contributed to two-thirds of the woodfuel produced in Kinshasa (Schure *et al.*, 2014). Most of the charcoal producers are mainly villagers residing in these areas of production (Schure *et al.*, 2014). Charcoal is mainly produced from specific tree species due to the different qualities preferred by the customers. Schure *et al.*, (2014) found out that 22% of the producers in Kinshasa and Kisangani preferred forest trees for charcoal production because of their large size and quantity.

In South African countries like Zambia, the dominant vegetation cover is the miombo woodlands covering up to 2.7km² (Kutsch *et al.*, 2011). The rural communities depend on this ecosystem for different services such as medical products, wild fruits, timber and poles for construction, mushrooms and roots for food and fuel (Campbel *et al.*, 1996). However, degradation is on the rise as a result of, among other reasons increased charcoal production due to increased energy demands for the urban population. Over the years the proportion of cleared land in the region exceeded that which is left to regenerate making charcoal production unsustainable (FAO, 2005; FAO, 2010).

In Uganda, charcoal production is primarily confined to areas connected or close to the three major urban centers that are Jinja, Entebbe and Kampala (Khundi *et al.*, 2011). For instance, Nakasongola has experienced forest degradation and deforestation but still is the primary source of charcoal consumed in Kampala markets (Shively *et al.*, 2010). Just like Zambia, production is mainly carried in woodlands and is a precursor to cultivation. The main tree species in the woodlands include *Grewia* spp., *Combretum* spp. *Treminalia* spp, *Albizia* spp and *Allophylus* spp comprising of 81% of the national total forested area (MWLE, 2001). Actual production in Uganda takes place

on private and communally owned lands as compared to relatively small percentage taking place in public forests (Kisakye, 2001; Knopfle, 2004).

There are different sources of wood used for charcoal production in Kenya. A majority of charcoal producers (86%) source wood from private farms (MoE, 2002; Mutimba and Barasa, 2005). In Kitui county, a ban was imposed in 2012; however private farmland supplied wood for production in areas of Mutomo, Muthaa and Katene. Similarly, in Baringo, *Prosopis juliflora* within private lands is used for charcoal production. Wood Residue from cleared farmlands for instance in Kajiado is harnessed for charcoal production making space for livestock keeping, pasture production and agricultural activities (Mugo and Ong, 2006). Studies have shown that *Prosopis juliflora* produces high calorific charcoal and its impact on the environment due to its invasiveness. However environmental impacts as a result of charcoal production from these species remain undocument especially in the drylands.

Different tree species are used for charcoal production based on availability and quality of charcoal factors. The most preferred 45% and used 38% tree species for charcoal production include *Acacia tortilis*, *Acacia senegal*, *Acacia mellifera*, *Acacia polyacantha* and *Acacia xanthophloea* (Mutimba and Barasa, 2005). *Acacia* spp and *Commiphora* spp are the dominant species in dryland vegetation, and its wood is usually characterized as hard, dense and with low moisture content making it suitable for charcoal production (Mutiti, 2010; Njenga *et al.*, 2013). The good quality characteristics of charcoal from *Acacia* spp make it more preferable in African drylands as compared to other species (Oduor *et al.*, 2012). In his studies Friederich (2016) found out that charcoal from *Acacia* spp has a higher calorific value of 8000 kcal per unit kg than charcoal from bamboo (6900 kcal per kg) and teak (6500-7000kcal per kg). Charcoal from *Prosopis juliflora* is also suitable because of its high calorific value, however the focus has always been on the

hardwood species that produce dense and high calorific value charcoal that is most preferred by consumer.

Characteristics among the kilns used for charcoal production differ from one region to another. Some of the kilns used include the traditional earth kiln, improved earth kiln, drum kiln, casamance kiln, portable metal kiln, brick kiln and the retort kiln. However, charcoal quality and the efficiency of these kilns is dependent on the moisture content of the wood, the stacking of wood, the kiln type, the volume of wood used, tree species the surrounding climatic conditions and the skills of the producer (FAO, 2017).

The traditional earth kiln is used for small scale production and has an efficiency of 15-20% with carbonization taking an average of 5-10 days (Oduor *et al.*, 2006). The construction process of the traditional earth kiln requires minimal cost and material hence is mostly preferred by most charcoal producers. Although it uses minimal cost in its construction, traditional earth kiln uses a lot of biomass for charcoal production because of its low conversion rate. On the other hand, the improved earth kiln/casamance is also used for small scale production. Unlike the traditional earth kiln, it offers room for controlled airflow during carbonization with the use of chimneys and has a higher efficiency of 26-30% (Oduor *et al.*, 2006). However, stacking of wood before lighting up need precision which may be time-consuming for the charcoal producers. Because of the precision required in stacking wood, charcoal producers opt for convenience with the use of traditional earth kiln. Traditional earth kiln is commonly used in Asia and America (Chidumayo and Gumbo, 2013). Locally, 99% of charcoal producers use traditional earth mound kiln in Kenya (Mutimba and Barasa, 2007). However, despite the existence of modern kilns, the relatively low-cost implications in setting up, high labour intensive traditional earth kiln, flexibility and size and shape remain the attractive factors among a majority of producers.

In Kenya, the drum kilns can be categorized into either the KEFRI or the Maxwell design. Although both have a similar efficiency (20-30%) and are portable, the Maxwell type yields cleaner charcoal as compared to the KEFRI design (Oduor *et al.*, 2006). Although the drum kiln is vital in utilizing the small twigs which could have been discarded as waste, the dominant use of traditional earth kiln necessitates the use of more biomass because of its low conversion rate. The portable metal kiln is adaptable for both small and large scale production. Despite the advantages of portability and higher efficiency of 26-30% as compared to the traditional earth mound, the metal kiln is costly (Oduor *et al.*, 2006) and hence the preference for rudimentary technologies. The Maxwell Kinyanjui farm Kitengela has practically demonstrated utilization of pruned parts of indigenous species such as *Acacia* spp. rather than whole tree harvesting and hence minimizing dryland degradation. Although the use of pruned parts is practiced in private farmlands for small scale production, there is little knowledge on utilization of small twigs for invasive species and its impact on the environment.

There are three types of brick kilns, i.e. the half orange kilns (50-60%), dome shaped kiln and rectangular-shaped kiln both having an efficiency of 28-30% (Oduor *et al.*, 2006). The half orange kilns are suitable for small wood materials as compared to the dome and rectangular-shaped that are suitable for large production. Although they are costly and require transportation of wood to the production site, the use of the brick kiln for charcoal production using *Prosopis juliflora* makes it suitable for commercial purposes. This is because the yield ranges from 80-120 bags depending on the volume of the kiln. In Brazil, the leading charcoal producer globally, the brick kiln is mostly used to produce commercial charcoal (Bailis *et al.*, 2013). Githumbuini Estate and Kakuzi are some of the renowned agricultural companies that have used brick kilns in charcoal productions and as such documentation of its use has not been advanced in *Prosopis juliflora* drylands. On the

other hand, the retort kiln has the highest efficiency of 70-80% (Adam, 2009). It is mostly used for large scale purposes. For instance, it is used in Gallman Kuki Laikipia ranch which utilizes *Tarconanthus camphorates* species for charcoal production. The use of the retrort kiln is costly and requires large materials and thus could work well where there are organized production groups such as charcoal producers groups and association. However, there is little information on its use in the drylands.

2.1.2 Impact of Charcoal Production on the Environment

Charcoal production impacts the immediate environment in the short term and long term. The magnitude of charcoal production impacts on the local environment is influenced by specific production systems (technologies and practices) whose adoption largely relies on contextual socio-economic and cultural factors (Iiyama *et al.*, 2017). Although this is the case, charcoal production can be used a tool for managing *Prosopis juliflora* because of its invasiveness. However, impacts differ based on the characteristics of the area (historical and present) and management practices before and after tree harvesting (Hosier, 1993). Different studies have been done with conclusive evidence on the underlying effects of charcoal production systems on the environment. Figueirôa *et al.*, (2006) evaluated *Caesalpinia pyramidalis*, *Croton sonderianus*, *M. teneiflora* and *Mimosa ophthalmocentra* tree species and found out that different cutting methods influence their propagation and regenerative growth rate. In their findings, *Mimosa* spp are more prone to die in the wet season as compared to the other four tree species studied. Hence, the recommendation such as coppicing¹ as a management practice should not be made during the rainy season.

¹ Defined as periodical cutting back of a tree or shrub to stimulate growth

Unmonitored charcoal production contributes to environmental degradation. An assessment was done in Kitui County on land cover change and degradation as a result of charcoal production indicated a positive relationship between woodland cover and the estimated distance to the main road (Kiruki *et al.*, 2017). Increased land cover changes was as a result of the increased population. Therefore, more vegetation is cleared for the construction of more extraction roads leading to the kiln site. Although charcoal production contributes to land cover change, *Prosopis juliflora*'s invasiveness characteristic and production of high calorific value charcoal make it sustainable for charcoal for drylands areas. However, documentation on the impacts of charcoal production on land cover change has majorly focused on hardwood species, unlike the invasive species.

Charcoal production contributes to both vegetation degradation and biodiversity degradation. Vegetation degradation encompasses a decrease in the amount and quality of grass, herbs and woody species in the environment (FAO, 2009). This is caused by deforestation, overgrazing, fires and cultivation. On the other hand, biodiversity degradation refers to the decrease in species, ecosystem diversity and genetic resources resulting from decreasing the function of habitats for affected flora and fauna (FAO, 2009). Continued utilization of hardwood species for charcoal production in dryland areas contributes to loss of biodiversity. Studies on the charcoal driven deforestation on fragile rangelands revealed an average tree loss of 2.8% per year with little regrowth (Oduori *et al.*, 2011). Similarly, invasive species such as *Prosopis juliflora* limits growth of other species (Choge *et al.*, 2002). Over years, more emphasis has focused on the negative environmental impacts of using hardwood species for charcoal production in Kenyan drylands than invasive species.

The method of biomass harvesting for charcoal production contributes to varying magnitude of environmental degradation. Selective choice of the trees for harvesting leads to the loss of the composition and physiognomy in a woodland hence altering its ecological importance (Ahrends *et al.*, 2010). In a case study of Mutomo, Kitui County, findings indicated that charcoal production in unprotected woodlands deteriorated the overall tree species richness, spread and Shannon diversity (Ndegwa *et al.*, 2016). Selective harvesting targeting hardwood species is preferred by charcoal producers as these trees provide quality and high calorific value charcoal (Iiyama *et al.* 2014b; Kattel, 2015). Regionally, the size and species of trees harvested describe selective harvesting systems in Uganda and the United Republic of Tanzania (Shively *et al.*, 2010). Different studies have documented the changes in landcover as a result of *Prosopis juliflora* invasiveness such as loss of agricultural land and grazing land. However, the magnitude of harvesting methods impact on biodiversity tends to focus on hardwood species in the drylands leaving out invasive species.

2.2 Charcoal Demand and Utilization

Woodfuel accounts for 6% of the global primary energy supply, a measure slightly higher than any other form of renewable energy (REN21, 2015). In SSA, biomass fuels meet energy demands for over 60% of the population (IEA, 2017). Charcoal is a dominant energy source used for cooking and heating in most households in urban areas. However, its consumption differ from one country to another, characterized by frequent purchases in small quantities with little concern about the economic and environmental implications of their use (Shively *et al.*, 2010).

Between the year 1997-2000, Dar es Salaam consumed 471,000 tonnes of charcoal annual while her neighbour Uganda's city of Kampala consumed approximately 200,000-230,000 tonnes yearly (Seidel, 2008). On the other hand, Kenya's yearly charcoal consumption was estimated between

1.6-2.4 million tonnes (Mutimba and Barasa, 2005) with Nairobi city consuming 10% of the total (Njenga *et al.*, 2013). Charcoal used in Nairobi county comes from different sources such as Kitui, Makeni, Tana River, Kwale, Narok, Baringo, Kajiado and Garissa. A majority of urban households (87%) and 34% of rural households depend on charcoal as their primary energy source (Mugo and Gathui, 2010). On the other hand, the use of firewood is prevalent among 89% of rural households as compared to 7% of urban households (Mugo and Gathui, 2010). Although found invasive, *Prosopis juliflora* in the drylands not only produces high calorific value charcoal but also provides additional benefits to the rural households.

The charcoal value chain encompasses activities right from production to consumption. Activities in the production stage involves tree growing, wood production and harvesting. Some of the players involved in the value chain include landowners, charcoal producers, agents/middlemen, traders (transporters, wholesalers and retailers) and consumers. Consumers buy charcoal in bags, buckets and tin of different dimensions. Once harvested, charcoal is packaged into bags which are then stationed at the production point or taken to the collection centres near the production locality. The movement of charcoal from the producer to the consumer is done either directly or through indirect avenues such as the use of traders and transporters who act as a link between the two. However, different regulations govern the transportation and sale of charcoal in Kenya thus impacting its production. The extent of their impact on charcoal from the invasive *Prosopis juliflora* remains undocumented.

Transportation is a key component in the value chain as it links the production centres to the urban areas. Different means of transportation are employed depending on the size and distance covered. Schure *et al* (2014) noted that with the increasing depletion of forests, the distance between the market places is similarly increasing thus necessitating increase in the cost and means of

transportation. Example of transportation means includes use of animals like donkeys, hand cart, bicycles, motorcycles, pick-ups and lorries.

Production of charcoal results in charcoal dust as remnants. Charcoal dust as a byproduct is mainly found at the handling and loading places mostly the selling points and comprises of 1-15% of the total charcoal in the supply chain (Mugo *et al.*, 2007). If left unused, the estimated total loss of charcoal in the form of charcoal dust in Uganda was 5-15%. However, research has revealed that the use of briquettes mainly made from charcoal dust contributed to 16% more cooking fuel among urban households in Nairobi (Njenga *et al.*, 2013). Therefore, charcoal dust provides an alternative to meet households' energy needs not only in the urban areas but also in the rural areas. However, the extent of the practice in charcoal production in the *Prosopis juliflora* drylands is not document.

2.3 Governance of Charcoal Production in Kenya

Several policy instruments and institutional frameworks in Kenya recognize the importance of charcoal as a source of energy. The extent of their focus is extensive but not limited to land utilization, tree growing, charcoal production, transportation, sale and utilization. In this section, the study reviewed some of the institutions and policy instruments that govern charcoal production in Kenya. The institutions include the Kenya Forest Service (KFS), National Environmental Management Authority (NEMA), Energy Regulatory Commission (ERC) and Kenya Bureau of Standards (KEBS). On the other hand, the policies comprise of the National Environment Policy 2013, Sessional paper No.3 of 2009 on National Land Policy, Energy Policy 2004, Sessional Paper No. 5 of 2005 on Forest Policy and National Policy for Northern Kenya and Other Arid Lands.

As mentioned above, these policies influence the production of charcoal, marketing and utilization. They all stipulate that production should be carried sustainably to avoid deforestation and land

degradation. Producers are required to use modern kilns to reduce wastage of wood and charcoal while consumers are also required to use energy-saving cookstoves, respectively.

2.3.1 Policies within the Charcoal Sector

National Environment Policy 2013

The policy was formulated as part of the requirements of the Vision 2030 and the Constitution of Kenya 2010. The policy advocates for the management of ecosystems and sustainable use of natural resources. Among the ecosystems listed include forest, marine, freshwater and wetlands, mountains and arid and semi-arid. The policy mentions charcoal burning among other factors such as overgrazing, human settlement, expanding agricultural activities, uncontrolled fires and fuelwood collection as the main threats to ASALs. It also recognizes that there is a need for restoration of the already degraded ecosystems such as freshwater and wetlands. Among the proposed strategies include the institutionalization of payment for environmental services.

Under the consumption and production patterns section, the policy advocates for the integration of environmental tenets in a multidimensional approach for sustainable development. It further calls for consideration of environmental costs associated with each level of consumption and production in the overall valuation of the environmental goods provided. The Millennium Ecosystem Assessment identified among other provisioning services such as charcoal are obtained from forests and other woodlands ecosystems (Butler *et al.*, 2003). Further, the policy advocates for coming up with methods and tools that will ensure maximization of resource utility through the use of environmentally friendly technologies. It is against these provisions that the government seeks to provide incentives to encourage clean, efficient and environmentally friendly production technologies such as the drum kilns, brick kilns etc.

Sessional Paper No. 3 of 2009 on National Land Policy

The objective of the policy is to reduce poverty through the provision of sustainable growth and secured land rights. Among important issues addressed in the National Land Policy include land tenure, land use management, land administration, institutional framework and implementation framework. Under the land tenure, land in Kenya is designated as government land, trust land and private. In governance issues, the policy states that the government shall enact a Land Act to govern all classifications of land. Land use management encompassed in the policy stipulates that the government shall put in place strategies for long term growth and development of both urban and rural areas.

Further, it stipulates for the protection of land by both policy and law due to the resource (land) having multiple values. These values include, a) land as an economic resource that should be managed economically, b) land as a finite resource calling for sustainable use, c) land as a cultural heritage calling for consideration for the future generation should and d) land as an important resource equitably accessed for all members of the society for their livelihoods. A summation of the provisions of the Land Policy is the immense support geared towards sustainable land-use practices and also calls for environmental restoration through sustainable management of land-based resources. Example of land-based resources includes forests and woodlands which are an important source of wood for charcoal production, wetlands among others. Even though forests and woodlands provide wood biomass used for charcoal production, the policy does not explicitly mention charcoal production systems nor their impacts on the environment which this study seeks to find out.

Energy Policy 2004

The two major objectives of the policy are i) to ensure sufficient energy supplies that sustainably meet demand with minimal environmental impacts from associated biomass energy and ii) ensure availability for an enabling environment for efficient and sustainable production, distribution and marketing of charcoal (Mugo and Gathui, 2010). The policy has put in place avenues through which the objective is going to be attained such as capacity building for technology exchange, licensing of charcoal production for sustainable utilization, creating an enabling environment for private sector participation and formulation of a national strategy to spearhead research on biomass energy. The Kenya Draft Energy Policy 2014 classified biomass charcoal included as one of the renewable energy as derived from naturally occurring resources. It further emphasized the large potential that can be harnessed in tapping into the existing renewable resources such as income generation, job creation, and enhancing energy security. Despite charcoal production playing a major role in meeting energy needs of urban households in Kenya, the policy is silent on the impacts associated with charcoal production systems in Kenyan drylands more specifically Marigat sub county.

National Forest Policy, 2014

The National Forest Policy, 2014 envision to address sector challenges. Some of the strategies proposed by the policy include good governance, transparency and accountability, equity and improved living standards. This policy aims to introduce a chain of custody for forest products such as timber and other wood products (charcoal included). It, therefore, proposes measures such as compliance certificates and certificate of origin for exporters involved in forest products. The policy also calls for a national forest resource monitoring system which will help keep track of the trend hence effectively and periodically know the forest cover in the country for action.

The policy also calls for enriching community participation in forest management through devolving community forest conservation and management. Dryland forests play a significant role in the livelihood of the people living in ASALs areas. The policy, therefore, calls clarification of tenure and property rights for sustainable supply of drylands forest goods such as charcoal, silk, edible oil, gums and resins.

National Policy for Northern Kenya and other Arid Lands

The policy is also known as the ASALs Policy. Its main objective is to provide a platform for boosting sustainable development in ASALs region based on the existing condition of the residents' lives. Therefore, the policy aimed at diversification of livelihood dependency sources other than food aid. Specifically, chapter 2 of the policy seeks to change people's perception that the inhabitants of these regions are less equipped in terms of common land exploitation as compared to those in privately owned lands. Dryland farming is mentioned in section 5.4.4, recognizing the importance agro-pastoralism, and marginal farming plays to the livelihoods of these communities. Therefore the policy calls for a complementary approach into their main source of livelihood, i.e. pastoralism and hence recognizes inadequacy in the production technologies.

On the contrary, there are no properly instituted interlinkages between drylands and other communities as best practice on sustainable production. The policy recognizes solar and wind as potentials sources for renewable energy in the ASALs areas but fails to recognize biomass in the same category despite its role in the livelihoods of people in these areas. It also mentions dryland products such as non-wood products such as resin, gum and medicine which are products obtained from both shrubs and trees species in these regions an important source of charcoal.

The Vision 2030

The Vision 2030 represents Kenya's development blueprint covering the years 2008 up to 2030. Kenya aims to be transformed into a middle-income country with quality life among her citizens in a clean and secure environment. The policy is divided into three sections, namely, the political pillar, the economic pillar and the social pillar. Whole and retail trade falls under the economic pillar as one of the six key priority sectors. Technology and innovation is a vital foundation of the vision 2030 anchoring the three pillars. For improved charcoal production systems, this will encompass the use of improved technologies such as the drum kiln, improved earth kiln, Casamance among other which have higher wood conversion ratio compared to inefficient technologies such as the earth mound kiln (Oduor, 2006) and hence promoting artisan industries that modify and make these kilns.

Energy plays an important role in realization of the economic pillar of Vision 2030 and charcoal is one of the sources for most urban households. However, the development plan has not specifically stated the role of charcoal in meeting the energy demands with special focus on the national grid.

County Integrated Development Plan-Baringo County

Covering the second phase of 5 years (2018-2022), the Baringo CIDP envisions a county that is resilient, attractive, competitive, secure and with high standards of living to her residents. Within the forestry products, the plan recognizes among others charcoal production as one of the value chain development activities. The plan endeavours among other priority 10-year sectoral intervention to enhance access to reliable and affordable energy through connection to the national grid. However, it does not specify the role and potential charcoal production through the use of *Prosopis juliflora*.

2.3.2 Institutional Framework within the Charcoal Sector

Forest Conservation and Management Act no. 34 of 2016

Established under the Forest Act 2005 Kenya Forest Service (KFS) operates as a cooperate body under the Forest Conservation and Management Act no. 34 of 2016 (referred to as the Act). Under the provisions of the Act, KFS is charged with the responsibility of conserving, protecting and managing of forest resources. However, drylands areas are not captured in this provision. In addition utilization of invasive species such as *Prosopis juliflora* for charcoal production is not clearly stipulated. Other functions include receiving and issuance of licenses or permits with regards to forest resources utilization, promoting capacity building through forestry education and training and where requested, help individual and community forest owners in preparing management plans. Under the Forest (Charcoal) Rules, 2009 also known as the Forest (Charcoal) Regulations, KFS is responsible for the issuance of licenses for the production and transportation of charcoal. However, the Act does not specify the type of species that the charcoal being transported should be from. Further, the regulations give powers to forest officers to inspect respective premises or vessels of charcoal transportation on either a regular basis, when a breach of non-compliance is suspected or when necessitated before issuance of the permit. Thus, the focus tends to be directed after production has occurred leaving out the actual wood sourcing ,utilization, type of technology used which also impacts the environment.

Commercial charcoal producers are required to register under a charcoal producer association (CPA) before being issued with the license by KFS. However, individuals producing charcoal for their use are not required to be members of CPAs (Government of Kenya, 2005; 2016). Commercial charcoal producers are also required by KFS to obtain a harvesting permit before issuance of charcoal production license. The harvesting permit is issued by the forest officer upon authenticating letter from area chief confirming ownership of the land of the trees to be harvested

(Gok, 2005; Mbuti, 2009). Instances where one need to transport charcoal from one the production point to the market, KFS is charged with the mandate of issuing movement permits. However, this permit which is not transferrable and only applicable from 6 am to 6 pm is only issued to the transporter upon producing certificate of origin and receipts showing the purchased charcoal (Gok, 2005; 2016). Although the issuance of the transportation permit aims to prevent illegal charcoal trade, it neither specify the transportation of charcoal from invasive species nor the type of technology in the production phase.

EMCA Act 1999

National Environmental Management Authority (NEMA) is established under EMCA Act 1999 (Revised 2015). NEMA is a national regulatory agency with the mandate of supervising and coordinating matters touching on the environment. Chief among other functions for NEMA is ensuring proper management and utilizations of environmental resources sustainably through the integration of environmental consideration into development policies, plans, programmes and projects. Other functions include taking stock of the natural resources such as forests which are an important source of wood for charcoal production, wetlands, drylands, aquatic and marine among others within the country specifically their use and conservation. It also looks into different land use patterns and advice on the anticipated magnitude of environmental impacts. Section 18 establishes county committees who are charged with developing county environment strategic action plan which addresses environmental matters. *Prosopis juliflora* is confined to few counties Baringo county being one of them. Although studies have shown that charcoal production negatively impacts the environment, the Act is silent on the role of the committee in the management of invasive species such as *Prosopis juliflora* through charcoal production.

Standards Act Cap 496

Kenya Bureau of Standards is established through the Standards Act Cap 496 of the Laws of Kenya. Under the Act, KEBS is a standards body mandated to promote the competitiveness of goods and services in the country. KEBS can only achieve its obligation i) through the use of measurements, standards, testing and quality assurance (MSTQ), ii) by improving the quality of life and iii) supporting government policies aimed at protecting consumers, eradicating trade barriers and promoting fair trade and at the same time health, safety and environmental protection². However, in the production of charcoal, different technologies are used for charcoal production from different tree species. Although, there are two standards relating to sustainable charcoal use, i.e. Kenya Standard KS ISO 1841-1:2005 and Standards KS ISO 17225-1:2014, Specifications on the type of technologies for specific tree species are not clearly outlined. The two standards focus on cookstoves and clean cooking solution and fuel quality specifications for solid biofuels including charcoal.

Energy Act, 2006

Energy Regulatory Commission (ERC) is established under the Energy Act, 2006. ERC is mandated to regulate petroleum, electricity and renewable energy sectors. ERC is therefore mandated to regulate production, conversion, distribution, supply, marketing and use of renewable energy. Example of renewable energy sources includes wind, solar, geothermal, hydro and biomass energy. ERC defines bio-energy as energy obtained from solid, liquid and gaseous biomass and it encompasses charcoal, fuelwood, ethanol, biogas and bio-diesel. Even though ERC is mandated with Energy Act, 2006 in development of codes and standards in renewable energy

² Standards Act (Cap 496 of the Laws of Kenya)

sector much emphasis is aimed at the petroleum, geothermal, wind and solar energy sector despite the role charcoal plays in providing reliable and cheap energy.

2.3.3 Regulations within the Charcoal Sector

The Forest (Charcoal) Regulations, 2009

Also referred to as charcoal rules 2009, requires charcoal producers to have consent from landowners before harvesting trees, apply for the production license from the KFS Zonal office and have recommendation done by local environmental committee. The KFS Zonal manager is mandated to verify the authenticity of the documentation before issuance of the production license. Instances where more than three bags are to be transported, the Rules have mandated KFS to issue a movement permit to such transporters upon payment of license fee prescribed. Specific documentation required includes the certificate of origin and purchase receipts. The KFS Zonal officer is in charge of verifying these documents before issuance of the movement permit. At the selling points, the rules require sellers to have on display business permits from their respective local authorities, and a record of a copy of the movement permit and certificate of origin and receipts of sale. Although the certificate of origin can help to trace the source of the charcoal, it does not specify the technology used in the production phase. For consumers, the rules require them to have energy conservation plans initiatives such as use of improved cookstoves.

The Baringo County Sustainable Charcoal Production Act, 2016

An Act of the Baringo County Assembly aimed at promoting sustainable charcoal production, transportation and sale of charcoal. The jurisdiction area of the Act includes all forests and woodlands within the county. The Act calls for all commercial charcoal producers to form charcoal producer associations. Under subsection 1, the Act requires these association to enforce

conservation/reforestation plan within their localities, conduct charcoal production sustainably and among other functions. However, the Act does not specify the harvesting methods applicable for different tree species in the county and the type of technology to be used. The committee formed under this Act is mandated to issue operational license to person associations engaged in commercial charcoal production, despite a similar role being played by the KFS zonal officer. In moving charcoal from one place to another, the Act stipulates that such consignment should have a valid charcoal movement permit issued as provided by the Act. In addition to the movement permit, the charcoal being transported should also have a certificate of origin and valid receipt from the seller. In terms of trade, the Act prohibits sale of charcoal from unlicensed charcoal producers. Even though the Act bans charcoal from other counties unless allowed as provided by the Act, the mechanism of charcoal identification only focuses on the trade routes.

2.4 Theoretical Framework

To accomplish the objectives of the study, the assumptions of the sustainability theory provided the basis for explanation and predictions of the research variables. In addition, the theory enabled the researcher to giving reasons for the existence of the study problem.

Sustainability Theory

This study is anchored on the sustainability theory which has evolved since its conceptualization by the Bruntland Commission in 1987 (Stoddart, 2011). Sustainability refers to the ability to maintain or improve the condition and availability of a resource putting in mind intergenerational equity (Stoddart, 2011). There are three components of sustainability, that is the environment which entails maintaining the earth's life support systems for instance ecosystems services such as carbon sequestration, soil erosion control. The social component encompasses maintaining the

community's capacity that fosters effective participation and equality among all persons. Lastly, the economic aspect ensure the economic welfare that provides non-declining standards of living for the present and the future generation.

The sustainability theory is relevant for this study in that it explains the interconnectedness of ecological, social and economic systems. Therefore, the theory brings an understanding on how different people relate to the environment as a result of internal' factors such as biosphere attitudes/associations, self interests, traditions and openness to change (Hawcroft and Milfont, 2010). The choice of the production system by the charcoal producers may bring more yield to the farmer at the expense of the environment or benefit the environment at the expense of reduce charcoal yield hence informing the personal normative decision-making and values. As such, the linkage between the societal, economic and environmental will inform the study on sustainable charcoal production policy options and management options for invasive species in Marigat sub county.

2.5 Conceptual Framework

The conceptual framework for the study was based on the increased demand for dense and high calorific charcoal results in increased exploitation of slow-growing indigenous tree species for charcoal production in Marigat sub county. Charcoal is used in most urban households for cooking and heating purposes with dense and high calorific value charcoal from indigenous trees preferred most among consumers. However, overexploitation of these species leads to environmental degradations. The use of *Prosopis juliflora* which regenerates fasts and is suitable for charcoal production not only meet the increasing demand but also offers solutions to manage its invasiveness increasing livelihood sources through farming and livestock keeping. Therefore, effective policy will encourage management and utilization of invasive species through sustainable charcoal production. Nevertheless, creation of awareness and charcoal branding through associations needs to be done to encourage consumption (See Figure 2.1).

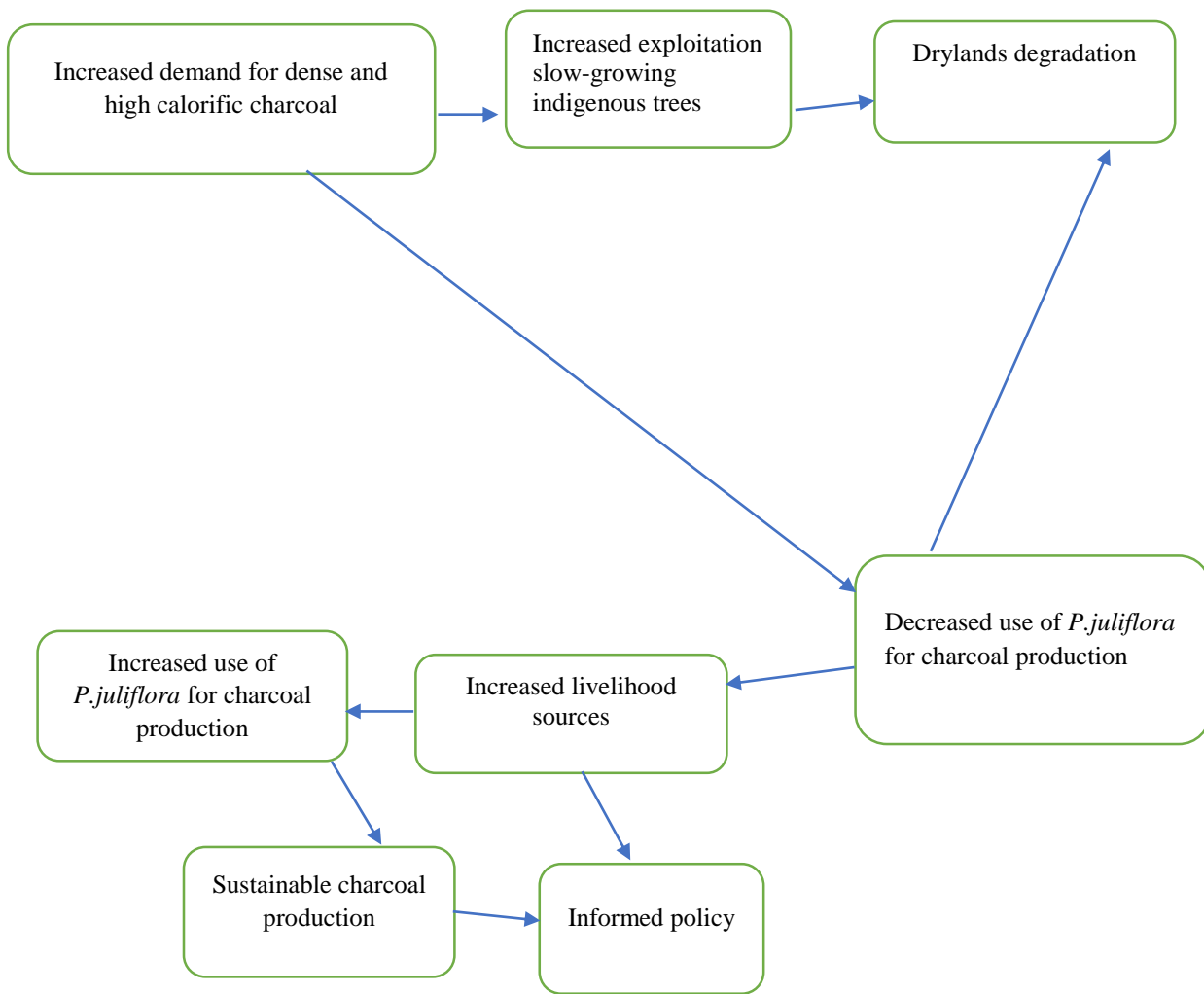


Figure 2. 1: Conceptual framework

Source: Author's Construction, 2019

2.6 Study Gap

There is a large pool of literature on the environmental impacts of charcoal production in the drylands using hardwood species. Focus on the impacts of charcoal production has been on the use of hardwood species more specifically the physiognomy and biodiversity loss. However, the invasiveness characteristic of *Prosopis juliflora* not only threatens biodiversity of Marigat sub county but also loss of agricultural and grazing land for the community members. Moreover, the use of improved kilns has been documented in private farms, there is little information on the use of invasive species in Kenyan drylands. Therefore, there is a knowledge gap on the production systems impact on the use of *Prosopis juliflora* for sustainable charcoal production. In addition, literature has shown that different regulation govern charcoal production, however it is not clear on their approach on production, trade and utilization of charcoal from the invasive *Prosopis juliflora* which the study seeks to answer.

CHAPTER THREE: METHODOLOGY

This chapter discusses the methods used in carrying out this study. They are grouped into different subsections and they include, the study site, study design, sampling and sample size determination, data collection methods, data entry and analysis and ethical considerations.

3.1 Study Site

This study was done in Marigat sub-county of Baringo County. Marigat sub county was selected because it is a major charcoal production area. In addition, Marigat sub county was chosen because *Prosopis juliflora* not only threatens biodiversity but also studies have shown that it produces high calorific charcoal preferred by consumers and hence can be used as a management tool to control its invasiveness. Geographically, Marigat sub county is located 250km west of the Nairobi city and has an altitude of 1067 metres above sea level (m.a.s.l),.

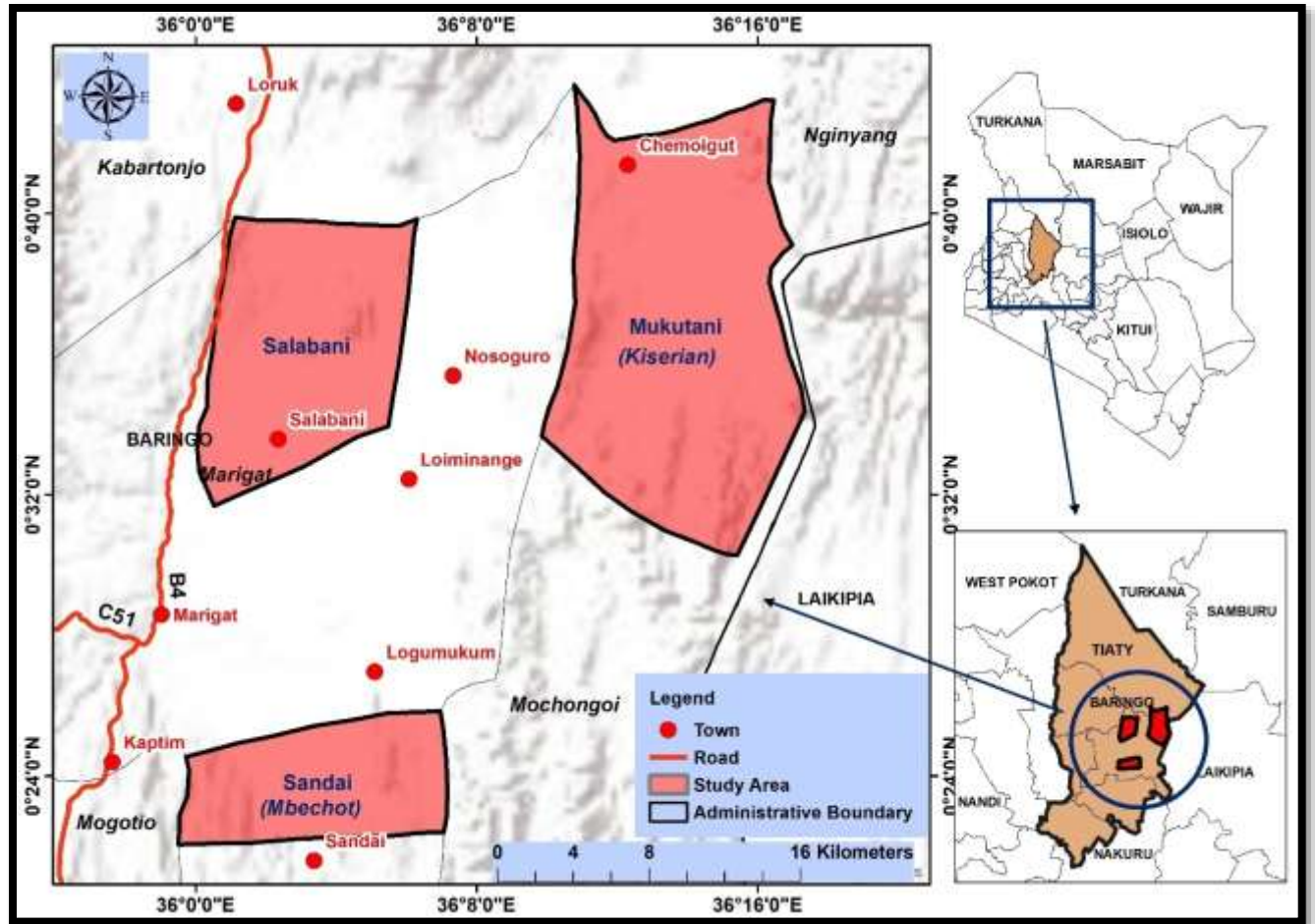


Figure 3. 1: Administrative boundaries map of the study area

Source: Author's Construction, 2019

Climate: In Marigat sub county the annual average weather conditions differ with the altitude of the area. Rainfall in the highlands is between 1000mm to 1500mm and in the lowlands is between 300-700mm per year (CIDP, 2013). The rainfall patterns can be characterized by a bimodal distribution with April and November receiving the highest amounts (Olang 1988). Temperatures range between a minimum of 10⁰C to a maximum of 35⁰C with the humidity recorded relatively low. The climate in study area varies, from humid highlands to arid lowlands.

Vegetation: Most parts of Marigat sub county are classified as arid and semi-arid. The dominant vegetation in valley floors of the study area is *Vachelia spp* mainly deciduous shrubland and

evergreen forests in the highlands (Mwangi and Swallow, 2008). *Acacia spp* mainly *Acacia tortilis*, *Balanite aegyptica*, *Boscae spp* and bushes of *Salvadora persica* are some of the native vegetation in Marigat Sub County (Andersson, 2005). However, *Prosopis juliflora* currently dominates most areas of the study area stretching from lowland flats surrounding areas of Lake Baringo and the northern and southern areas of Lake Bogoria (Undersson, 2005; Ng *et al.*, 2017).

Poverty index: In terms of poverty index ranking, Marigat sub county nationally has 60% poverty and the county at large is ranked 15th out of the 47 counties (Gok, 2011). Factors causing high poverty levels in the area include inadequate and unreliable rainfall, poor infrastructure especially road network, absence of organized market structures for farm produce and inability to access credit facilities. The impact of the high poverty level is greatly felt among pastoralist, farmers and female-headed households, disabled and landless persons (CIDP, 2013).

Livelihood: The main crops grown includes beans, sorghum, millet and watermelon while the main livestock reared in the study area are the east African Zebu cattle. Other animals reared include goats, sheep and donkeys. Beekeeping, pasture/hay, hides and skin and poultry are some of the additional economic activities carried out to supplement income and livelihood diversification (CIDP, 2013).

Energy access: In Marigat sub county, the main sources of energy include firewood, charcoal, electricity, LPG, kerosene solar and geothermal. Government efforts in rural electrification saw 2346 connections done in the year 2010-2011(CIDP, 2013). The presence of *P. juliflora* offers the potential for electricity generation; however, currently it is being harnessed for charcoal production.

3.2 Study Design

The study adopted a mixed methods research design, a blend of both qualitative and quantitative data (Creswell, 2014). The rationale for choosing this study design is because it allowed a comparison of different perspectives deduced out of both quantitative and qualitative data. By assessing the different production systems, the researcher aimed to find out their environmental impacts in Marigat sub county and thus deducing the sustainability of charcoal production in Kenyan drylands.

3.3 Sampling and Sample Size Determination

Simple random sampling technique was used to select 332 charcoal producer households from 6 sub locations. Therefore, all charcoal producers had an equal chance of being selected for the study. In this study, the sample size was determined by the Cochran formula as shown below.

$$n = \frac{Z^2 pq}{d^2}$$

where, n = the required sample size; Z = the selected critical value of desired confidence level (at 1.96 for 95% confidence level); p = the proportion in the target population estimated to have characteristics being measured; $q = 1 - p$; d = the level of statistical significance set at 5% (standard value of 0.05). With the study having no prior documented number of charcoal producers in the area, Fisher *et al* recommended 50% of the population to be used. With an error of 5% and the confidence coefficient of 95%, the sample size was determined as follows,

$$n = \frac{(1.96)^2 (.50)(.50)}{(.50)^2} = 384$$

In consultation with well-acquainted area forest officers and local leaders, 6 sub-locations namely (Kiserian, Salabani, Iling'arwa, Eldume, Ng'ambo and Maji Ndege) were randomly selected in

Marigat sub-county. The selection was based on high prevalence of charcoal production and presence of *P. juliflora* in the areas. A census was done for the six sub-locations and the population was found to be 3002 households. Out of these, only 2453 households produced charcoal representing 81.71% of the total households in the study area. Since the target population was less than 10,000, Mugenda & Mugenda, (2003) recommends that the final sample estimate (nf) be calculated as follows:

$$nf = \frac{n}{1 + \frac{n}{N}}$$

Where nf is the desired sample size (if target population <10,000); n is the sample size (when target population >10,000); and N is the target population. This resulted to a desired sample size of 332 households.

3.4 Data Needs and Sources

To fully answer the research questions, the study sought socio-demographic and production systems among charcoal producers. Both primary and secondary data sources were used. Primary data sources included, a household survey of charcoal producers, observation and participatory rural appraisal (PRA) with the community members and stakeholders involved in charcoal production. The primary data encompassed charcoal production systems and household characteristics of charcoal producers. Secondary data sources helped the study infer the existing policy and institutional frameworks governing charcoal sector. The sources included books, journals, government reports national policies and county development plan and the internet.

3.5 Data Collection Methods

For collection of primary data the researcher used a household questionnaire, an observation checklist and a participatory rural appraisal as discussed below. Secondary data were collected through desktop review.

3.5.1 Household Questionnaire

A household survey for the charcoal producers was done. A semi-structured questionnaire was used to capture household data. It comprised of their knowledge on traders' and consumers' preferences, current production systems, socio-demographic and economic characteristics and lastly land management practices. The questionnaires were administered with the help of enumerators who were conversant with the local dialect. The village elders and the chiefs played a key role in making the households aware of the survey exercise and hence providing assurance with regards to the information shared.

Table 3.1: Number of questionnaires administered to charcoal producers per sub-location

Sub-location	Number of questionnaires administered
Salabani	47
Nga'mbo	91
Iing'arwa	45
Maji Ndege	21
Kiserian	45
Eldume	83
Total	332

3.5.2 Participatory Rural Appraisal (PRA)

A participatory rural appraisal (PRA) was conducted to understand the different production systems in the study area. The PRA covered situational analysis, different gender roles in charcoal production, resource distribution, and charcoal stakeholder analysis, prioritization of new technology and the way forward in responding to both the policy and market preferences. There were 102 male and 58 female participants in total for the six sub locations. Mobilization of the participants was made possible with the help of the local leaders. In attendance were the area forest officer, county environment officer and a representative from the Lake Bogoria conservancy.

3.5.3 Observations

Through direct observation, the researcher recorded how different tree species were harvested, charcoal production technologies used, different land uses where charcoal production had taken place, and the different biomass management, within the study area.

3.5.4 Secondary Data

Secondary data was obtained from books, journals, government reports from ERC, KFS, national policies and county development plan and the internet. The literature review was conducted to enable the researcher understand the different policies and institutions governing the charcoal sector in Kenya. In addition, secondary data was collected to supplement primary data collected and hence forming a strong basis in answering the study objectives.

3.6 Data Entry and Analysis

Data entry was done using open data kit (ODK) tool later imported to Microsoft Excel for processing. The data was analyzed using Statistical Package for Social Scientist (SPSS) version 21 and STATA version 13 software. The data was analyzed using descriptive statistics and results presented as summary frequencies, charts and tables.

3.7 Ethical Considerations

Before administering household questionnaires, the researcher sought permission from the relevant authority mainly the chiefs. The randomly chosen respondents were also asked voluntarily to participate in the study. For instance, the researcher assured the respondents of their confidentiality of any information as data collected represents the situation holistically on the ground and hence policy recommendations given will not be biased in any way.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter, the results of the study and discussions are presented. It starts with the description of the charcoal production systems in the study area. A description and analysis of the environmental impacts of charcoal production systems in Marigat sub county are also discussed. The chapter concludes with detailed evaluation on how different policies and institutional frameworks support sustainable production systems in Marigat sub county.

4.2 Charcoal Production Systems

This section discusses charcoal production systems used in Marigat sub county and compares the difference among socio-economic characteristic of charcoal producers such as gender and education levels. Charcoal production systems discussed include biomass harvesting methods, tools used for biomass harvesting, type of tree species and technology used for charcoal production.

The dominant method of biomass harvesting for charcoal production in the study area was clear harvesting/felling (61.6%). According to the interviewed charcoal producers, clear harvesting created space for farming activities and also worked best in managing the invasive *Prosopis juliflora* within their farms. Selective harvesting was used by 21.4% of the respondents whose target was to allow maturity of other tree species within the farm. Similar findings by FAO (2017) indicated that using selective harvesting not only increased the maturity of the tree but also the yield from a mango tree. Pruning method is used by 15.8% of charcoal producers and most of them use it on *Acacia sp* because the harvesting of whole native trees was prohibited. Collection of deadwood/stumps was the least preferred method of tree harvesting (1.3%) as most of the

respondents depended on charcoal production as a significant livelihood hence not economically viable in terms of yield produced (Table 4.1).

Table 4. 1: Methods of biomass harvesting

		Responses		Percent of Cases
		N	Percent	
Methods	Clear harvesting	245	61.6%	74.0%
	Selective harvesting	85	21.4%	25.7%
	Pruning	63	15.8%	19.0%
	Collection of dead woodstump	5	1.3%	1.5%
Total		398	100.0%	120.2%

Simple tree harvesting tools were used for cutting trees in the study area. Among the respondents interviewed 46% cited using a panga for cutting their trees for charcoal production, while 35.5% were using a power saw (See Table 4.2). A half tank of power saw sold for KES 400 as the cost of hiring. Charcoal producers indicated that using power saw in cutting trees reduced the workload, many logs are harvested and are readily available.

Table 4. 2: Tools used for biomass harvesting

		Responses		Percent of Cases
		N	Percent	
Tools	axe	116	16.8%	34.9%
	panga	318	46.0%	95.8%
	powersaw	245	35.5%	73.8%
	others	12	1.7%	3.6%
Total		691	100.0%	208.1%

There were different sources of labour among the charcoal producers interviewed. Charcoal production took place mostly in the afternoon after other farming activities are completed in the morning hours. Household members, both male and female (42.2%) were engaged in charcoal production on their own. When schools were closed, or even the weekends, charcoal production is a family endeavour among 35.7% of the respondents interviewed as illustrated in Table 4.3. In some instances where production was done once in a while or involved massive production, 22.1% cited sourcing labour from casuals. This is relevant because it is consistent with findings by Asiwal *et al.* (2018) that households characteristics influence the possibility of sourcing labour source in farmland activities. Therefore, it can be argued that household characteristics such as household size influence the choice of labour source for charcoal production.

Table 4. 3: Labour sources for charcoal production

N =(332)		Responses		Percent of Cases
		N	Percent	
Labour sources	individual	155	42.2%	46.7%
	family	131	35.7%	39.5%
	Casuals	81	22.1%	24.4%
Total		367	100.0%	110.5%

4.3 Environmental Impacts of Charcoal Production Systems

The study found out that 88.5% of the respondents used *Prosopis juliflora* as the main charcoal production tree species, while 9.8% used *Acacia* spp. The availability level of *Prosopis juliflora* was abundant among (82%) of the respondents due to its invasive and fast-growing nature (See Table 4.4). Similar findings by Choge *et al.* (2002) indicated the spread of *Prosopis juliflora* has impacted both agricultural and grazing lands.

Table 4. 4: Tree species used for charcoal production

N=332		Responses		Percent of Cases
		N	Percent	
Tree species	<i>Prosopis juliflora</i>	307	88.5%	93.3%
	<i>Acacia</i> spp	34	9.8%	10.3%
	Others	6	1.7%	1.8%
Total		347	100.0%	105.5%

Prosopis juliflora is invasive, and as such, charcoal producers interviewed use it to produce charcoal as a management tool. Clear cutting is the dominant practice among 72.9% of charcoal producers interviewed. They claimed that land that charcoal production has taken place produced higher yield of farm crops than where production has not taken place, hence the drive for more open land echoing findings by Njenga *et al.* (2017b). Similar findings were made by Bartlett *et al.* (2018), who concluded that economic investment in mass production of charcoal from *Prosopis juliflora* was highest (5476US\$ ha⁻¹) among livelihoods of rural people in India. . Pruning is another management practice used by 26.8% of the charcoal producers in managing *Prosopis juliflora* while 0.3% used coppicing (Figure 4.1).

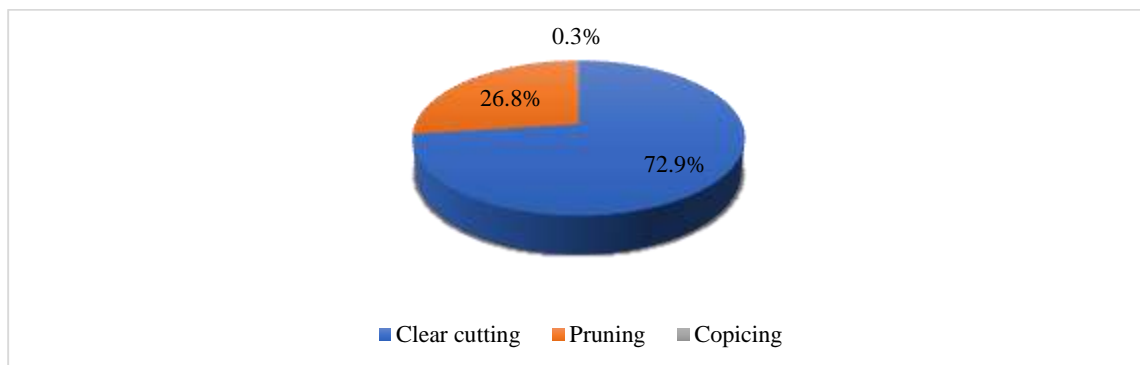


Figure 4. 1: Wood management practices for the main charcoal production tree species

Source: Field Survey, 2019

All the charcoal producers interviewed reported to use traditional earth mound kilns for charcoal production. According to Mutimba and Barasa (2005), 99% of charcoal producers in Kenya use traditional earth kiln for charcoal production. Similar to the study area, traditional earth kilns are commonly used because they are easy to construct. In addition, other factors in Marigat sub county such as impassible roads hinders the use of stationary kilns such as the drums kilns that require transportation of wood. The findings also indicated that the average production run and charcoal yield for the traditional earth kiln was 4 days and the 7 bags respectively (See table 4.5) as echoed by findings by Oduor *et al.*, (2006). Even though the traditional earth kiln has low wood-charcoal conversion rate (15-20%) (Oduor *et al.*, 2006), necessitating more *Prosopis juliflora* trees harvesting. This opens up more space for other trees species to grow and grass for their livestock.

Table 4. 5: Charcoal production run and kiln yield

	Production run	Kiln yield
N	332	332
Mean	3.51	6.17
Std. Deviation	1.45	3.63
Minimum	1	1
Maximum	14	30

4.3.1 Improved Technology Consideration

Traditional earth kiln is considered inefficient thus resulting in poor quality charcoal production. Based on its poor wood conversion rate to charcoal, there is a need for charcoal producers to use improved technology. From the study, 90.1% of the respondents were willing to consider use of improved technology in charcoal production compared to 9.9% who did not. From the study, 22.2% of the charcoal producers interviewed cited that they prefer less tedious improved

production technology. The use of traditional earth kiln requires little work in its setting up unlike other improved kilns such as drum or brick where there is precision in wood measurement. However it is prone to harsh weather conditions such as heavy rains as shown in Plate 3. In their findings, Njenga *et al.* (2016) noted that the use of improved gasifier stove for instance involved additional work hence limiting its use among rural households, unlike three stone open fire. The results also indicate that they desired to have improved charcoal quality (large particles) (20.6%) from the improved production technology. Based on their income, a majority of the charcoal producers earn below KES 20,000 per month and prefer an affordable improved production technology (18.8%). Other factors considered in the adoption of the improved technology include increase in output, environment considerations, training, and increased market price of the output (Table 4.6).

Table 4. 6: Factors considered in adopting improved charcoal production technology

Factors	Responses		Percent of Cases
	N	Percent	
High Output quantity	42	11.1%	13.4%
Quality charcoal (big particles)	78	20.6%	24.9%
Affordable price of kiln	71	18.8%	22.7%
Efficiency (high speed of wood conversion rate)	18	4.8%	5.8%
Environmentally friendly	31	8.2%	9.9%
Less tedious	84	22.2%	26.8%
Training	23	6.1%	7.3%
Increased market prices	20	5.3%	6.4%
others	11	2.9%	3.5%
Total	378	100.0%	120.8%

4.4 Policy And Institutional Framework for Sustainable Charcoal Production Systems

This section discusses the interconnectedness between various institutions governing technology use, wood management and harvesting and quality of charcoal produced and their mandate was discussed. The existing policies, regulations and institutions touching on charcoal production systems in Kenyan drylands were reviewed and gaps in the promotion of sustainable charcoal production identified. The policies discussed in this section included the Forest Policy of 2014, the Energy Policy of 2004, National Environment Policy 2013, the National Land Policy of 2009, the National Policy for the Sustainable Development of Northern Kenya and Other Arid Lands of 2012 and the Vision 2030. Covered in this sub-section is the Forest (Charcoal) regulations 2009 and the Baringo County Sustainable Charcoal Production Bill, 2014. Some of the institutional frameworks reviewed in this section include the Kenya Forest Service (KFS), National Environmental and Management Authority (NEMA), Energy Regulatory Commission (ERC) and Kenya Bureau of Standards (KEBS).

Forest policy of 2014 proposes measures and actions aimed at addressing the forest sector challenges. Among the initiatives the study found out include developing forest resource base, national climate change response strategy, and developing a chain of custody system for timber and wood products which includes charcoal. The policy recognizes the role played by dryland forests in sustaining the livelihood of the people in ASAL areas. The policy states that there is potential for afforestation in these areas contributing towards the country, achieving 10% tree cover. Further, the policy notes that livelihood improvement of the people residing in ASAL areas depends on clarity on tenure and property rights, having better processing technologies and availability of markets for non-wood products. Fuelwood and woodfuel significantly contribute to the livelihood of the rural population. From the study, charcoal production is a significant income-

generating activity to 88% of the charcoal producers interviewed offering an alternative source of income to farming. Therefore, better production technologies should not only address non-wood products as stated by the policy but also include charcoal production, taking advantage of the fast-maturing *Prosopis juliflora* in the area.

Objective 5 of the policy targets to support forestry on community and private land through small and medium-sized forest-based enterprises. The study noted that it is not clear on how the policy aims to achieve the objective other than organizations within the community. CPAs offers the best opportunity to achieve this objective as mobilization of her members by developing woodlots within their farms is easier for members than it is for non-members. However, only 12.2% of the charcoal producers interviewed belonged to CPAs in the area making the realization of the objective an uphill task. The study noted that the implementation of the charcoal rules 2009 that requires all commercial charcoal producers to belong to CPAs remains unfulfilled therefore forming the basis of an uphill task in fulfilling objective 5 of the policy.

The overall goal of the national environment policy 2013 focuses on the use and management of environmental and natural resources such that both the present and future generations experience quality life. Section 4.6.2 of the policy seeks to support sustainable conservation and management of environmental and land resources as provided by the constitution and the National land policy. The study noted that one of the main threats pointed out in fragile ecosystem is charcoal burning. However, production of charcoal using *Prosopis juliflora* not only produced high calorific value charcoal but also enhances biodiversity. The policy has critical interventions proposed to combat the effects of charcoal burning to the environment they include but not limited to adopting efficient measures for long term ASAL resource utilization, empowering communities in management of

these resources and mainstreaming dryland issues into development plans and policies at the national level.

The study also noted that the policy has identified the idea of incentivizing investment in clean, efficient and environmental-friendly charcoal production technologies to encourage sustainability. However, there was no existing plan on giving incentives on the use of improved production technologies, as previous attempts to introduce drum kilns in the study area did not last for long before charcoal producers reverted to the use of traditional earth kiln.

The overall objective of the energy policy is to ensure development needs are met through cost-effective, quality and adequate supply of energy while putting into consideration environmental matters. In the woodfuel sector, the policy recognizes that biomass accounts for approximately 68% of the total primary energy consumption. From the study finding, sources of biomass identified include forests, woodlands, grasslands, farmlands and plantation. In defining biomass, the policy consists of wood fuel (firewood and charcoal) and other agricultural residues. The policy identifies that there is a challenge in promoting sustainable biomass harvesting. Therefore, it recommends further studies aimed at coming up with innovative technologies as a potential intervention to wood wastage at the production level. However, the policy does not mention biomass energy as a potential source of renewable energy as more emphasis lies with solar, wind, hydropower and biogas energy. Despite the role charcoal plays in meeting households' energy needs and also in provision of income to the producers in rural areas especially the drylands, study noted that the draft National Energy and Petroleum Policy of 2014 aims to do away with the use of wood fuel, charcoal by the year 2022 (Ministry of Energy and Petroleum, 2014).

Like the energy policy 2004, sustainability is at the heart of the National Land Policy as it envisions the county to have efficient, equitable and sustainable use of land for development. In line with the government's development plans such as the Vision 2030, the main goal of the policy is to secure rights over land and provide for sustainable growth. In Kenya, land is classified as public, community or private (Constitution, 2010). The policy defines private land to include individual parcel held on a freehold or leasehold tenure, community land as land legally held, managed and used by a particular community as provided by the Land Act and public land as land that is neither private nor community land and as defined by the Act. Therefore, the study noted that the policy recognizes private land held on freehold or leasehold tenure promotes establishment of competitive enterprises such as establishment of woodlots for commercial purposes.

The policy also sought to have communities' right of access to resources they depend upon and advocates for allocation of titles to a particular community legally owning land. Community Land Boards were also established and are charged with the mandate of managing access to these lands. With regards to sustainable charcoal production, the study noted that the policy is silent on the exploitation of fragile lands and the land-based resources especially those on the verge of degradation such as woodlands which are an important source of wood for producers in these areas.

The national policy for sustainable development of northern Kenya and other arid lands of 2012 refers to Northern lands and other Arid Lands as ASALs (Arid and semi-arid areas). It recognizes that the region faces chronic food insecurity and other challenges such as population increase, degraded ecosystems and climate change. Despite the challenges, the policy recognizes the potential these areas have in terms of renewable energy both from solar and wind. Other natural resources identified with the sand and gravel of the area for construction sector, non-wood products

such as gums, resin and medicine. However, the policy does not include the potential for biomass as a source of renewable energy as re-growth replenishes the harvested trees.

The main goal of the policy is to facilitate and fast-track sustainable development in ASAL areas through increased investment. The policy falls short in recognizing the potential of invasive species such as *Prosopis juliflora* both in contributing to the 10% tree cover and a source of charcoal production tree species due to its fast maturity. The government's approach to ensuring sound land and natural resource management; the government aims to do away with the invasive species in these areas is not sustainable. Such an approach does not go in tandem with the provisions of the Agriculture (Farm Forestry Rules) 2009 which requires 10% farm tree cover as well as threatens the livelihood of these charcoal producers. Therefore, the use of improved charcoal production systems and sustainable wood management such as coppicing, thinning offers avenues for ensuring sustainable livelihood for the charcoal producers.

The vision 2030 recognizes that farms and drylands provide the needed avenue and space of increasing tree cover to 10%. It calls for integrating of appropriate tree species hence addressing the gap in meeting production of quality charcoal in the market. However, the plan is silent on addressing issues of invasive species which when adequately managed produced through the introduction of woodlots and use of sustainable tree harvesting methods such as pruning and coppicing will result into production of quality charcoal. Advancement of Sustainable Development Goal (SGD)⁷ influences the attainment of the other SGDs such as those on poverty, quality life, food security, gender equality, climate change etc. Sustainable charcoal production through the use of improved kilns contributes towards the reduction of emissions of greenhouse gases. Similarly, charcoal production using *Prosopis juliflora* in Marigat sub county contributes to

increase biodiversity as more grazing lands for the local pastoralist community is obtained hence diversifying their livelihood option leading to quality life.

The Baringo county integrated development plan which cover the years 2018-2022 criticizes charcoal as a major cause of environmental degradation in the county. This is despite the role charcoal production plays as a major livelihood source of charcoal producers. With regards to sustainable charcoal production, the plan is silent in its 10-year sectoral intervention aimed to enhance access to reliable and affordable energy. However, it states that charcoal production is one of the causes highlighted by the plan to cause environmental degradation in Baringo county. The mentioned areas include, Muktani, Mochongoi, Ilchamus, Emining wards among others (CIDP, 2013). The study noted that the potential use of the abundant *P.juliflora* in charcoal and power production remains untapped with more county resources channelled towards the last mile power programme.

The forest (charcoal) rules 2009 aim to bring sustainable production, sale and transportation of charcoal in the country. However, the rules are silent on commercial charcoal production using invasive species as in the case of Marigat sub county. Similarly, at the county level, the Baringo county sustainable charcoal production Bill, 2014 is a direct reflection of what is contained the Charcoal rules 2009. It explicitly outlines the procedures to be adhered to in the production, sale and transportation of charcoal within the county and for those intended to be sold outside its jurisdiction. However, it duplicates the provisions of the charcoal rules without having not considered the role of charcoal production from *Prosopis juliflora*. In taming inter-county trade, the Act is silent and weak on charcoal certification mechanisms and hence allowing difficulties

with identifying charcoal with its source in an effort to protect indigenous trees on the verge of extinction.

The Forest Act 2005 provided for the establishment of Kenya Forest Service charged with the mandate to manage, protect and conserve all forests within the country. Under the Constitution of 2010, the Act was repealed to Forest Conservation and Management Act of 2016 putting into consideration the functions of KFS in the devolved government. Therefore, issues of utilization of *Prosopis juliflora* are managed at county level unlike at the national level. Under Section 7 of the Act, issuance of permits is recognized as a form of authorization of forest activities done by KFS. At the time of the study, the charcoal transportation permit and production permits were not issued with producers in the PRA citing the effects as a result of logging ban. The provisions for exclusive use license should be applied for areas where invasive species exist for charcoal production.

For commercial charcoal producers transporting their charcoal to other areas, KFS requires that a charcoal movement permit is accompanying their consignment as stipulated by the Charcoal rules 2009. The permit is only given upon production of a certificate of origin and purchasing receipts. The movement permit is paid for, as illustrated in Table 4.7 unlike the certificate of origin. However, currently the movement permit is not issued as a consequence of the logging ban despite continued consumption of charcoal.

Table 4.7: Charcoal movement permit charges

Charcoal weights	Charges
1 tonne-5 tonne	Kshs. 1000
6 tone-8 tonnes	Kshs. 1500
8 tones and above	Kshs. 2000

Source: Field Survey, 2019

The Environmental Management and Coordination Act (EMCA) (No.8 of 1999) (revised in 2015) established NEMA as a national entity charged with the mandate of overseeing and coordinating environmental matters. Charcoal production entails cutting down of part of or whole tree. Therefore, NEMA, under the Act is mandated to ensure that environmental degradation does not occur as a result of these activities. The Act has mandated NEMA to ensure that carried out for any major land use change. Charcoal production was mainly carried to pave way agricultural land with most of the charcoal producers citing not aware of any requirement for land-use change.

As provided EMCA 1999, NEMA has the mandate to publish and share manual and codes and guideline that aims to achieve environmental management. The study found out that NEMA's mandate tallies with the provisions of the Charcoal rules 2009 by the KFS, that requires all commercial charcoal producers in CPAs to have conservation plan for areas earmarked for charcoal production thus promoting sustainable charcoal production.

Established under the Energy Act 2006, Energy Regulatory Commission (ERC) is mandated to regulate petroleum, electricity and renewable energy sector. Among other functions, ERC is charged with the mandate to come up with standards and codes of practice for renewable energy. Biomass which includes firewood and charcoal has been recognized by the Energy Act 2019 as

renewable energy; however more emphasis focuses on geothermal energy production failing to underline the importance of charcoal and firewood in meeting energy needs of both urban and rural areas. Therefore, the development of standards and codes for renewable energy should extend to the use of improved production technologies and improved wood management for charcoal production.

In renewable energy subsector, ERC is charged with the role of enforcing renewable energy and EE regulations. Some of the regulations include the energy appliance performance and labelling regulation 2016, the energy (solar photovoltaic systems) regulation 2012, Appliances (energy performance and labelling) regulations 2018 and the energy (improved biomass cookstoves) regulations 2015. The study found out that there is minimal regulation geared towards charcoal production in terms of improved technology use and the source of biomass used for charcoal production. More efforts in the past such as adoption of efficient cooking technologies have always targeted the demand side to curb charcoal consumption leaving the supply side that has a greater impact on the environment unaddressed (Johnson et al., 2018).

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

The purpose of the study was to assess the sustainability of charcoal production in the Kenyan drylands, more specifically, Marigat sub county. Charcoal production remains a vital livelihood source among people in ASALs areas. Marigat sub county is one of these areas and explicitly endowed with *Prosopis juliflora* however its invasiveness threatens biodiversity in the study area. Studies have revealed that *Prosopis juliflora* species are suitable for charcoal production hence can be used as a tool for managing its invasiveness. Findings from the study show that charcoal producers largely rely on *prosopis juliflora* for charcoal production.

There were different charcoal production systems in Marigat sub county. All the respondents were using traditional earth mound kiln for charcoal production. From an economic point of view, the respondents attributed the low cost of construction as the reason as to why it is mostly used. Further, sourcing labour from family members helped in cut down the cost of production as compared to hiring casuals. Biomass harvesting is done mostly by clear harvesting for charcoal production mainly to pave the way for more grazing land and farming activities with some claiming that the cleared land was more fertile as compared to other barren lands.

The impact of charcoal production varied with different production systems. Clear harvesting of *Prosopis juliflora* for instance encouraged growth of other tree species and creation of more grazing land for the community. Similarly, the dominant use of traditional earth kiln among all charcoal producers limited the use of small twigs in charcoal production leading to wastage of tree biomass. In addition the use of traditional earth kiln with a low conversion rate (15-20%), as indicated by Oduor *et al.* (2006) necessitated sourcing of more wood for charcoal production.

From the different policies and institutional framework analysed, the study found out that there is inadequacy in controlling and guiding production activities especially in the drylands. For instance, despite government directives such as the logging ban, charcoal production from *Prosopis juliflora* was still permitted. However, charcoal producers cited having difficulties with charcoal movement. There was no clear guideline on identifying charcoal from the banned areas such as gazetted forests and charcoal from invasive species.

5.2 Conclusions

One of the objectives of the study was to characterize charcoal production systems in Marigat Sub County. From the study findings, all the charcoal producers interviewed used traditional earth mound kiln. The high proportion of traditional earth mound kiln users could be attributed to its low construction cost and adaptability in size and shape. However, 90.1% of the charcoal producers interviewed were willing to consider using new technology, a good indicator towards sustainable charcoal production in Kenyan drylands.

Marigat sub-county is endowed with the invasive *Prosopis juliflora* which matures faster as than the native trees in the area. Clear felling is the most used method of managing *Prosopis juliflora* in Marigat sub county among 72.9% of charcoal producers. This could also be as a result of the county government of Baringo ban on the use of native trees such as *Acacia* spp for charcoal production. Therefore, the study concludes that there is a positive impact on biodiversity as a result of the production systems used as charcoal production acts as a tool of managing its invasiveness.

From the reviewed policies and institutional framework, there is adequate support for sustainable charcoal production systems in Marigat sub county. However, much emphasis focuses on the trade, transportation and consumption side such as the use of energy-saving stoves with minimal intervention at the production end.

5.3 Recommendations

Based on the findings and conclusions, the study recommends that:

- I. Interventions should be geared towards imparting skills on the use of improved technologies such as drum kiln and improved earth kiln. Capacity empowerment on the use of new technology remains a priority; there is a gap in skills in terms of setting up of these technologies, wood sizes to be used in production and harvesting. Besides many charcoal producers are shying away from the use of new technologies such as drum kiln due to its low output. Therefore, policymakers should prioritize public education geared towards making charcoal producers knowledgeable on the importance of using low output technologies that maximize tree parts that will otherwise be wasted if used with other technologies.
- II. Voluntary best wood management practices geared towards mitigating negative impacts as a result of the production of poor quality charcoal should be applied hand in hand with the existing policies and institutional frameworks. They include the establishment of woodlots within the farms which are in line with the provisions of the Forest Policy 2014 and the energy policy 2004.
- III. Sensitization on the importance of producers forming and joining CPAs should be a priority by policymakers and government entities both at the national and county levels. It not only addresses the interests of the members but also offers an effective platform where individuals can pull resources together to purchase improved kilns hence reducing overdependence on donations from development partners and the government.
- IV. The Baringo County Sustainable Charcoal Production Bill, 2014 and the Forest (Charcoal) Regulations 2009 should be strengthened to include charcoal branding and certification. This will help in the identification of charcoal and its respective sources hence

encouraging the use of charcoal from *Prosopis juliflora*. In the long-run, indigenous trees that are facing extinction as a result of overharvesting to will be protected and at the same time protecting biodiversity in Marigat sub county.

- V. Environment Policy 2013 and the Energy Policy 2004 should be strengthened with the introduction of a framework for incentivizing the use of improved production technologies among charcoal producers.
- VI. The county integrated development plan for Baringo county should aim to include the role of charcoal in meeting households' energy needs, especially from *P.juliflora* and enhance mechanism in both research and monetary allocation aimed at facilitating sustainable production.

Areas for Further Research

Further research should be geared towards finding the economic value of the dominant charcoal production tree species (*Prosopis juliflora*) to inform specific policy intervention in harnessing its benefits. Comparative analysis should be carried out for a natural tree species dryland, and invasive species invested dryland in evaluating producers preferences for different production systems.

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APPENDICES
APPENDIX 1: HOUSEHOLD QUESTIONNAIRE

UNIVERSITY OF NAIROBI

Assessment of sustainable charcoal production in Kenyan drylands: A case of Marigat sub county

CONSENT FORM FOR HOUSEHOLD SURVEY QUESTIONNAIRE

My name is Siko Ignatius, from CASELAP, University of Nairobi. I am conducting a research on **Assessment of sustainable charcoal production in Kenyan drylands: A case study of marigat sub county**. The aim of the research is to understand the charcoal preferences among traders and consumers and their implications on the production systems I will be asking you some questions in the next 45 minutes. The information you share and data collected from you will be confidential, with no individual benefits or risks and purely used for academic purposes particularly for thesis writing which is part of the requirements to complete a Masters of Arts in Environmental Policy at the Center for Advanced Studies in Environmental Law and Policy (CASELAP), the University of Nairobi.

Kindly, do you mind some time to answer my questions?

Yes () No ()

If yes proceed with the interview and if no the interview must be discontinued.

SECTION 1: QUESTIONNAIRE IDENTIFICATION

Date.....	Name of interviewer.....
County.....	Sub-county.....
Ward	Sub location.....
Village.....	Name of town/market.....
Household ID No.....	Geographical location Latitude..... Longitude.....

SECTION 2: KNOWLEDGE OF THE TRADER AND CONSUMER PREFERENCE

Question 1.

Which of the following best describe your knowledge about trader and consumer charcoal preference

1. High ()
2. Intermediate ()
3. Low ()

Question 2.

Who are your main customers? (tick)

	customer	Tick
1	Local broker	
2	Transporter	
3	Wholesaler	
4	Retailer	
5	Consumers-household	
6	Consumers-institutions	

Question 3

Rank your main customer in terms of amount (percentage/proportion) of charcoal you sold in the last 12 months.

	customer	location	Rank	% of charcoal bought
1	Local broker			
2	Transporter			
3	Wholesaler			
4	Retailer			
5	Consumers-household			
6	Consumers-institutions			

Question 4.

What is your source of labour for charcoal production?

1. Individual
2. Family
3. Casuals

State the reasons why?

- 1.....
- 2.....
- 3.....

SECTION 3: CURRENT PRODUCTION SYSTEMS

Question 5.

What methods of tree harvesting for charcoal production do you use, what are the reasons for adopting them?

- 1. Clear felling Reason.....
- 2. Selective harvesting Reason.....
- 3. Pruning Reason.....
- 4. Collection of dead wood/ stump Reason.....

Question 6.

What tools do you use to cut trees?

- 1.
- 2.
- 3.
- 4.
- 5.

Question 7.

When did you start producing charcoal; Number of years

Question 8.

How often do you produce charcoal?

- 1. Weekly
- 2. Fortnight
- 3. Monthly
- 4. Others, Specify

Question 9.

Which months are you usually involved in charcoal production? (tick)

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Nov	Dec

Question 10.

What are the main reasons for your involvement in these months?

- 1. _____
- 2. _____
- 3. _____

Question 11.

What kind of kiln do you use in making charcoal?

- i. Earth-mound kiln
- ii. Drum kiln
- iii. Brick kiln
- iv. Casamance kiln
- v. Other Specify

Question 12.

How many days does the charcoal production take from kiln establishment/setting up to unloading?

.....Days

Question 13.

Do you dry wood before carbonization? Yes/no

If yes for how many days?

Question 14.

What is the average size (in metres) of such a kiln?

- i. Diameter.....
- ii. Height.....

Question 15.

On average how many bags of charcoal do you get from such a kiln? (.....) Bags

Less than 3	3-5	6-10	10-15	15-20	20-25	Over 25

Question 16.

What is the average price per bag (.....) KES

Question 17

Do you belong to a charcoal producers' association

Yes () NO ()

SECTION 6: CURRENT LAND MANAGEMENT PRACTISES

Question 25.

What is the size of your land in terms of:

1	Total land size from all parcels (acres)	
2	Tenure (with/without title deed, group ranch etc)	
3	land under crop cultivation%
3	land left fallow%
4	land under trees%

Question 26.

After charcoal harvesting, do you utilize the space occupied by the kiln? Y/N

If yes, for what?

.....

Question 27.

What is current and planned future land-use of the land where the trees were/are being harvested for charcoal production?

1. Current land use.....

2. Planned/future land use.....

Question 28.

After tree harvesting for charcoal, are there any management practices undertaken to support regeneration? (tick)

Yes ().....(Explain management practice)

No ()

Question 29.

What is the current level of availability of charcoal production tree species in the land? (tick)

1. Abundant (There are many trees of the preferred species and size)

2. Scarce (There are only a suitable few trees left in the farm)

3. Completely depleted (one can hardly find any trees of the preferred species and size)

APPENDIX 2: FOCUS GROUP DISCUSSION GUIDE

UNIVERSITY OF NAIROBI

Assessment of sustainable charcoal production in Kenyan drylands: A case of Marigat sub county

Participatory Rural Appraisal (PRA) Guide

My name is Siko Ignatius, from CASELAP, University of Nairobi. I am conducting a research on Assessment of sustainable charcoal production in Kenyan drylands: A case of Marigat sub county. The aim of the research is to assess sustainability of charcoal production in Marigat sub county. I will be asking you some questions in the next 1 hour. The information you share and data collected from you will be confidential and purely used for academic purposes particularly for thesis writing which is part of the requirements to complete a Masters of Arts in Environmental Policy at the Center for Advanced Studies in Environmental Law and Policy (CASELAP), the University of Nairobi.

(Begin with laying down the rules of the discussion. Before we begin, everyone should know that their participation is highly regarded and that there are no right or wrong answers. This is an open forum for everyone to be part of, and equal treatment applies to every member present. We will start with a quick introduction going round each to tell us their names and where they come from. Member of the research team will then introduce themselves)

1. What are your thoughts concerning our topic today?
2. According to you, what are the reasons for:
 - i. Producing charcoal full time?
 - ii. Producing charcoal periodically?
 - iii. Choosing specific tree species for charcoal production?

Tree harvesting Methods

3. Are there any specific trees species you prefer for charcoal production?
4. What characteristics do you use in identifying these specific tree species suitable for charcoal production?
 - i. From whom or where do you obtain information about these characteristics?
 - ii. Do these characteristics influence the quality of charcoal in terms of size, smoke, weight and ability to break?

If yes, Please explain

6. In terms of preferred harvesting methods, kindly fill in the table below

Preferred harvesting method	Reasons	What would make you change the harvesting method

Knowledge of Charcoal traders and consumer preference

6. Are you aware of the kind of charcoal traders and consumers prefer? I'd like to hear more of what you have heard about their charcoal preference.
 - i. If participants are unfamiliar with the charcoal preferences among traders and consumers, explain what it is. (consumers prefer heavy charcoal and that which burn for long)
Then ask: Does this sound like something you factor in during your charcoal production process?

Please explain.

- ii. If any have heard of these preferences, ask the following: What have you learned about this subject? From where or whom did you get the information?

7. Considering the whole charcoal production system, how do you meet these preferences;

- i. In terms of tree species do you think this type of charcoal can be produced? Please explain.
- ii. How should it be produced in terms of harvesting techniques?
- iii. What production and tree species harvesting methods have you used to meet charcoal preferences for both consumers and traders?

Charcoal production technologies

8. What kind of kilns do you use?

9. Is there any challenges you face with the use of these kilns?

10. Have you considered using new production technology apart from the traditional earth Kiln?

Please explain.

11. Have you heard of drum kiln and improved earth kiln? Kindly share with us your thoughts and opinions about these two improved charcoal production technologies.

- i. If participants are unfamiliar with these improved charcoal production, explain and show them pictures of what they are and how they work. Then ask: Does this sound/look like something people might be interested in?

Please explain.

- ii. If any has heard of the improved charcoal production techniques presented, ask the following: What have you learned/heard about these improved production techniques?
How did you get to learn/hear about them?

- 12. What are some of the advantages you have heard these improved charcoal production techniques?

- 13. What are some of the disadvantages you have heard about these improved charcoal production techniques?

- 14. Do you know anyone who has used drum kiln or improved earth kiln? What was their Experience?

- 15. Have you considered using them? Please explain.
 - i. As a charcoal producer, how would you react to these improved charcoal production technologies knowing that they require financial investment, unlike the traditional earth mound kiln method? Ask the women and men separately?

- 16. Anything else you would like to add or ask in our discussion today?

Thank you for taking your time to be part of this discussion!!

APPENDIX 4: OBSERVATION MATRIX
UNIVERSITY OF NAIROBI

Assessment of sustainable charcoal production in Kenyan drylands: A case of Marigat sub county

CONSENT FORM FOR OBSERVATION MATRIX

My name is Siko Ignatius, from CASELAP, University of Nairobi. I am conducting a research on **Assessment of sustainable charcoal production in Kenyan drylands: A case of Marigat sub county**. The aim of the research is to understand the charcoal preferences among traders and consumers and their implications on the production systems I will be asking you some questions in the next 45 minutes. The information you share and data collected from you will be confidential, with no individual benefits or risks and purely used for academic purposes particularly for thesis writing which is part of the requirements to complete a Masters of Arts in Environmental Policy at the Center for Advanced Studies in Environmental Law and Policy (CASELAP), the University of Nairobi.

Write a brief description on the following

Item	Description
Predominant kiln in use	
Nature of tree harvesting	
Predominant Wood management within the farms where charcoal production is taking place	
Packaging of charcoal produced	
Land use where charcoal has been harvested	

APPENDIX 5: PHOTOGRAPHS



Plate 1: Charcoal assortment before repackaging (left), packaging in tins (centre), buckets and bags (right)



Plate 2: Charcoal from Uganda (left) and charcoal from Baringo County (right) from *Acacia sp* (Thick in diameter) and from *Prosopis juliflora* (thin in diameter)



Plate 3: Traditional earth mound kiln