DETERMINATION OF FACTORS INFLUENCING ADOPTION AND CONTROL OF *Prosopis juliflora* IN MARIGAT, BARINGO COUNTY, KENYA

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DECLARATION

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DEDICATION

This thesis is dedicated to my husband Joseph Odhiambo and children who encouraged and supported me in my education.

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I am grateful to God for the good health and divine protection throughout my studies. I would like to thank Egerton University for giving me the opportunity to study in the institution. I am extremely grateful for the enormous help I received from my supervisors, Dr. Dickson L. Makanji and Prof. Abdillahi A. Aboud of Egerton University while carrying out my research work. I also thank Egerton University staff who took part in all the stages of my thesis preparation. I am grateful to the Director, Kenya Forestry Research Institute and management for supporting me in this project. I sincerely thank Dr. Joshua Cheboiwo, for his encouragement during proposal development, field research, data analysis and thesis writing. I also acknowledge the cooperation of the many respondents and people I met, who were fortrightly and generously volunteered information throughout my study. I am indebted to Mr. Samson Ojuga for the help he accorded me. This work would not have been complete without the understanding and support of my family and friends, to whom I am grateful.

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ABSTRACT

Prosopis juliflora was introduced in Kenya to address the increasing demands of forest resources and to improve the vegetation cover. The extent and spread of *Prosopis juliflora* is a threat to ecosystem (erosion of biodiversity, allopathic interactions and negative health on both animals and human) that supports livelihoods in Marigat Sub-county. To control its spread, several management and control technologies were promoted in the area in early 2004. They include clearing and planting pasture, charcoal production and killing of stumps with chemicals, among others. These interventions have not yielded the desired results. The aim of this research was to determine factors that influence people's adoption and utilisation of *Prosopis juliflora* for its management and control within the Arid and semi-Arid Lands. A socio-ecological survey was carried out using Semi-structured questionnaires with both closed and open-ended questions. A sample size of 337 households was randomly selected for the study in Marigat Sub-county. Socio-economic and demographic factors were considered. Chi-square was used to determine the differences between the mean variables. A regression model was used to identify determinants of *Prosopis juliflora* management technique with income and socio-economic characteristics as dependent and independent variables, respectively. Results showed land size, incomes from *Prosopis* products; age and household size significantly influenced the adoption of management and control technologies. Majority of the respondents (36.7%) were low adopters and utilizers of control techniques. Charcoal burning as a management and control measure was found to be the most utilised technique (24.8%) , fencing (12.6%)fuelwood(10.4%). The results also show that Socioeconomic and demographic factors influence adoption and control of *Prosopis julifora* Age (p=0.04), Household size (p=0.016) income (p=0.006). Thus, the government should adopt new strategies for sensitising the communities and entrepreneurs on the management of *Prosopis* invasion to enable its utilisation and other control measures.

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LIST OF ACRONYMS

CBD	Convention on Biological Diversity
CBO	Community Based Organization
CFA	Community Forest Association
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GISP	Global Invasive Species Programme
GoK	Government of Kenya
IS	Invasive Species
IMV	Improved Maize Variety
ISSG	Invasive Species Specialist Group
IUCN	International Union for Conservation of Nature
KEFRI	Kenya Forestry Research Institute
KGS	Kenya Gazette Supplement
KFS	Kenya Forest Service
NEMA	National Environmental Management Authority
NGO	Non-Governmental Organization
PU	Perceived Usefulness
PEOU	Perceived Ease Of USE
RoK	Republic of Kenya

CHAPTER ONE
INTRODUCTION

1.1 Background to the study

Prosopis species is one of the world's most invasive plants and is listed among the worst 100 species (Lowe *et al*., 2000 and Zeila, 2011). This is due to its ability to rapidly expand, colonising areas quickly and competing negatively with native species. This species has a wide evergreen canopy height of about 14 meters and is native to the Caribbean, Central, and North America (Pasiecznik *et al.,* 2001). Most invasive species have an advantage of being prolific seeders, producing large numbers of seedlings, and are hardy therefore easily establishing in degraded environments. Invasive species are most of the time introduced intentionally or accidentally in an area. After its introduction, they affect the environment negatively, affecting the socio-economic activities of the resident communities. On a global scale, the Mediterranean Basin, Middle East, and North America are regions with the highest risk of range expansion of *Prosopis* invasion. *Prosopis* has invaded millions of hectares of land in arid and semi-arid continents of Asia, Africa, Australia and Americas (Mwangi and Swallow, 2008).

There are 44 *Prosopis* species as recorded by (Burkart, 1976). Two of these species *Prosopis juliflora* and *Prosopis pallida* are exclusively tropical (Pasiecznik *et al.*, 2001). In Africa, *Prosopis juliflora* is believed to have invaded over 4 million hectares; threatening crop and rangeland production; desiccating water resources; and displacing native flora and fauna (Zimmermann *et al*., 2004 and Witt, 2010). The *Prosopis julifora* was first introduced in Africa through Senegal in 1822, South Africa in 1880 with a subsequent introduction to Egypt in 1900. It is hardy and can tolerate harsh climatic conditions with rainfall as low as 150mm. The tree has a red brownish rough bark and a deep taproot system. It grows rapidly, tolerates aridity, salinity and fixes nitrogen. *Prosopis juliflora* is none deciduous and a prolific producer of pods with high sugar content. The seed gum has the following sugars, Rhanase, fucose, arabinose, xylose, mannose, galactose and glucose that are of value to human (Shitanda *et al.,*.2013). On average, a mature tree may produce up to 40kg of pods per year with approximately 60 000 seeds (Alban *et al*., 2002, Ochola *et al*.2010).

In the early 1970s, *Prosopis* j*uliflora* was introduced in Kenya to address the increasing demands of forest resources and to improve vegetation cover (Esbenshade and Graige, 1980, Choge *et al.*, 2007 and Sirma *et al.*, 2008., Ochola *et al.* 2010). The introduction was near the coastal city of Mombasa, with seed sourced from Brazil and Hawaii. The species adapted and

naturalised very easily in Kenya, especially along the coastal region, and the communities gave it a name "Mathenge" (*Prosopis juliflora*) after the person who encouraged them to plant.

Prosopis juliflora was introduced in Baringo County in the early 1980s with the good intentions of curbing soil erosion and safeguarding the existing indigenous vegetation from overexploitation by the local population (Lenachuru, 2003 and Choge, *et al.*, 2007). The act was in line with the Kenya Forests Act cap, 385 which provided for management of forests. The contribution of *Prosopis juliflora* towards the rehabilitation of degraded areas and provision of timber, fuel, income and fodder to the local community has been significant in Baringo (Mwangi and Swallow, 2005 and Sang, 2009). However, the species turned out to be destructive to the community due to its rapid growth and spread. This prompted the Government to declare it a noxious weed in 2008 under the Noxious Weeds Act CAP 325. The declaration came into force in 2009 after its publication in the Kenya Gazette notice no 184 (GoK, 2009). The tree has outgrown the indigenous Acacia spp and occurs as a pure stand in many low lying areas around the shores of Lake Baringo and proximal areas.

There have been claims that the leaves of *Prosopis juliflora* produce negative health responses in goats damaging their' teeth and that its thorns may be highly poisonous to humans. The ecological implications of biodiversity loss associated with *Prosopis juliflora* raise important issues that require attention. In the National Environmental Policy 2012, *Prosopis juliflora* is listed among the main contributors to loss of biodiversity, that need to be controlled and contained to protect the environment in arid and semi-arid areas. The government through Kenya Forestry Research Institute (KEFRI) in collaboration with Kenya Forest Service (KFS) and non-governmental organisations (NGOs) took up the initiative to find innovative solutions in the management of *Prosopis juliflora*. After in-depth research, management through utilisation was embraced due to the initial high management cost of mechanical and chemical methods.

The government and other organisation then trained Farmers and key stakeholders on utilisation of *Prosopis juliflora* which has contributed significantly to the improvement of their livelihood (Pasiecznik *et al.*, 2001 and Choge *et al.*, 2006). To improve its utilization, an important legislation was enacted under the Forests Act No. 7 of 2005 section 59 that provided rules and regulations on the production, transportation and marketing of charcoal.

This legislation was gazetted in December 2009 as the Forest (charcoal) rules 2009, which legalised the burning of *Prosopis* species for charcoal enabling its control.

Recent studies and observations expose numerous beneficial traits of the *Prosopis juliflora* that Marigat households can utilise to enhance their livelihoods. For instance, Aboud *et al.* (2007) lists some seventeen (17) ecological and socioeconomic beneficial traits of *Prosopis .juliflora* as revealed by a survey conducted in the then Marigat division currently sub-county (Appendix 1). However, despite the potential effectiveness of the utilisation and management techniques as control measures, *Prosopis juliflora* continues to spread invading more areas, especially along rivers and roads. Making insights on human facet of invasion is an essential element for effective decision making. More research has been done on ecology and the impact with less being done in social aspects. Understanding of the social dimensions of *Prosopis juliflora* invasions is poor, and this is thwarting attempts to implement effective management to reduce the costs while, where possible, maintain some of all the benefits (Richardson, 2001 and Shackleton *et al.*, 2015).

While diffusion scientists, for instance, Rogers (1995), have proposed theories explaining people's adoption of innovations, including people's orientations and the nature of the innovations, other researchers, such as Hassan *et al.* (2002) and Hassan (2008), emphasise socioeconomic status of local communities as the great contributor to poor or lack of adoption. They argue that socioeconomic status is known to influence the types of activities people are engaged in as well as their interaction with natural resources. This position also influences the way they think, perceive and behave towards the adoption of innovations. There is, therefore, need to determine the socioeconomic and demographic factors that affect the adoption of management and control of the species in order to advice policy adequately.

1.2 Statement of the problem

Prosopis juliflora is an invasive species. Its rapid spread through the production of allelochemicals inhibiting co-existence with other plant species in Kenya presents many challenges. The species has out-competed indigenous Acacia species and occurs as pure stands in many low lying areas. Currently, it covers 66% of the land in Marigat Sub County and has the potential of invading more land due to its prolific seeding. Like many species that have both negative and positive effects, *Prosopis* has many contentious issues surrounding it, and management interventions have not yet reduced its negative impacts. There is, therefore, a dire need to determine factors that influence the adoption of good control practices that will dictate policies and enhance its sustainable management.

1.3 Research objectives

1.3.1 Broad objective

The broad objective was determination of factors influencing people's adoption and utilisation of *Prosopis juliflora* for its management and control within the Arid and semi-Arid Lands (ASALs) of Kenya

1.3.2 Specific objectives.

The specific objectives of the study were: -

i. To determine the influence of socioeconomic factors on the adoption and utilization of *Prosopis juliflora* among the households
ii. To determine the degree of *Prosopis julifora* control measures adopted and their utilisation among households
iii. To determine the influence of demographic factors on the adoption and utilisation of *Prosopis* among the households

1.4 Research questions

i. Which are the socio-economic factors that have influenced the adoption of *Prosopis julifora* among household?
ii. Which of the *Prosopis juliflora* management practices advocated by the government and NGOs have been adopted and the degree of their utilisation
iii. Which are the demographic factors that have influenced adoption of *Prosopis juliflora*?

1.5 Justification of the study

Prosopis juliflora in Kenya is found growing vastly in Baringo County its presence has influenced community livelihoods. There are laws governing its management within the Environmental Management and Coordination Act (EMCA), Seed and plant variety Act, the Agricultural Produce Act and the Plant Protection Act. The invasion of *Prosopis julifora* continues to be a threat and a key contributor to environmental degradation in the drylands of Baringo County. Earlier research work has concentrated mainly in the cost of eradication, its uses and ecological aspects, especially in Baringo. There exists a knowledge gap on factors affecting adoption of the management and control measures. Such information will be useful

in guiding *Prosopis julifora* management programs for policymakers and will contribute new knowledge to the body of science on invasive species control.

1.7 Scope of the study

The study focus was on Marigat Sub County of Baringo County. It was undertaken in four administrative locations of Salabani, Ngambo, Ilchamus and Kapkuikui, covering households in locations which are affected by *Prosopis julifora*. Data which was collected concentrated on socioeconomic and demographic factors that influence adoption and utilisation of *Prosopis julifora* management and control measures.

1.8 Limitation of the study

The data collected relied on recall of the respondents. However, due to seasonality for the sale of pods and use, it was not easy for the respondents to recall all the information that was required.

1.9 Definition of terms

The following terms are defined in the context of this study.

Adoption: The Action of choosing to use a technology

Control: Restraining an organism from expanding its population to a level that compromises the integrity of the ecosystem development.

Invasive species: An organism that expands its population rapidly to the demise of the local species, ecosystem development and even human health

Management: The control of the unwanted species by reducing their density and abundance to a level which does not compromise the integrity of the ecosystem and allows native species to thrive.

Utilisation: Making use of the species with the aim of reducing its occurrence and accruing benefit from it.

Innovation: A new idea, a practice that is perceived to be new by an individual.

Ecosystem: A complex of organisms and their environment interacting as a distinct ecological unit irrespective of political boundaries.

Establishment: A phase in the settling of a species in a new area such that it is able to reproduce without human assistance.

***Prosopis* innovations:** These are practices that are being disseminated to reduce and so control *Prosopis* invasiveness to generate ecological and financial benefits to the people.

Household head: refers to the member of a house who is the primary decision-maker of the household (KNBS, 2010).

Livelihood: refers to income-generating activities determined by natural, social, human, financial and physical assets and their access such as farming, livestock keeping and business (Ellis, 2000).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Prosopis juliflora is a pioneer species that rapidly colonises denuded landscapes. It is listed among the invasive alien tree species in the world which were introduced to provide benefits to local communities. *Prosopis juliflora* as a multipurpose dryland tree is native to South America, Central America and the Caribbean. It has naturalised in many parts of the world (Africa, Asia, and Australia) during the last 100-150 years (Pasiecznik *et al.,* 2001). Numerous *Prosopis* taxa are recognised as significant invaders across large parts of the world (Pasiecznic *et al.*, 2001 and Lowes *et al.,* 2000). The 'usefulness' of *Prosopis* has led to the large scale introduction of five species in particular (*P. chilensis, P. glandulosa, P.juliflora, P. pallid and P.velutin*) and the subsequent naturalisation and invasion of the taxa and their hybrids (Kannan *et al.*, 2014). *Prosopis juliflora*, commonly called Mesquite in the USA, has several synonyms including *Acacia cumanensis* Willd and *Acacia juliflora*. *Prosopis juliflora* thrives in most soils including; sandy, rocky, poor and saline soils within an altitude range of 300-1900 m above sea level. It is able to survive in areas with low annual rainfall or very long dry periods only if the root is able to tap groundwater within the first few years. The rainfall zones are 100 mm or less in dry coastal zones to 1500 mm at higher altitudes. The optimum temperature for germination is 30-35^{o} C with germination decreasing rapidly at temperatures below 20^{o} C. It can tolerate day time shade temperatures of over 50^{o} C and soil temperatures in full sunlight as high as 70^{o}C in Africa and Asia (Pasiecznik *et al*., 2001). Since they are deep-rooted, which allows them to reach water tables, the trees are able to grow and fruit even in the driest of years, providing a buffer throughout the year. The tree is 3-12m tall, sometimes shrubby with spreading branches which are cylindrical and green. Its leaves are bipinnate, 1-3 pairs of pinnae which are 3-11 cm long; leaflets 6 to 29, generally 11 to 15 pairs per pinna. The legumes are straight with incurved apex, sometimes falcate, straw-yellow to brown, compressed, linear with parallel margins, stalked and acuminate. The endocarp segments are up to 25, rectangular to sub-quadrate, mostly broader than long. Seeds are oval and brown and are difficult to extract. It produces a large number of seeds which remain viable for decades with the ability to coppice after damage (Shiferaw *et al.*, 2004). The roots can efficiently utilise both surface and groundwater (Dzikiti *et al.*, 2013). This plant reproduces through seed, often once they have passed through the digestive tract of browsers- such as goats, camels, cattle and some wild herbivores.

Mature trees produce 20-100 kg of nutritious pods every year. *Prosopis juliflora* is spread along watercourses and run-off areas during periods of rain and then spreads laterally from these sites. It grows in dense impenetrable thickets often invading the land and even worse, encroaches on the river beds and canals blocking and causing drainage patterns to shift (Kool et al., 2014) uncontrollably. The plants can be very aggressive invaders and replace native species taking over rangelands. Adverse effects include complete loss of pasture and rangelands for both domestic and wild ruminants, depletion of water and the destruction of fishing nets and livestock and human diseases. Other impacts are loss of cropland, the cost of repairing tyres punctured or destroyed by thorns, and doctor's bills for treating thorn wounds. Dense stands of *Prosopis juliflora* can block irrigation channels, obstruct roads and block smaller trails completely affecting access to pasture, croplands, water sources and fishing areas. For example, Chemonke village in Kenya, farmers had to seek alternative settlement elsewhere because they had lost their land to *Prosopis juliflora* invasions (Mwangi and Swallow, 2005). *Prosopis* has also been recorded to cause increased mortality of *Acacia erioloba* and a reduction in the population stability of native tree species, due to competition for limited resources (Schachtschneider and February 2013 and Shackleton *et al.*, 2015).

Plate 1.1: *Prosopis juliflora* in Baringo

Plate 1 shows the typical characteristics of the species. In this case, the trees are growing near the road and form a thick impenetrable thicket. The trees are growing near a water body which can be seen in the background. In ASAL areas these water bodies are essential for humans as well as their livestock. *Prosopis juliflora* blocks access to the water resource and this has consequences for people who derive their livelihoods from these water bodies.

2.2 The Socio-economics of *Prosopis juliflora* species

Prosopis poses a major threat to rangelands, croplands and causes health problems of animals and human beings. It causes the overall loss of natural pasture, displacing of native trees, reduction in stocking rate, toxicity to livestock *(*Senait *et al., 2004).* A diet high in pods can cause mortality in sheep and goats due to a digestive problem. The pods contain cytotoxic alkaloids. Some people in Ethiopia believe that consumption of *Prosopis julifora* pods by camels causes flatulence diarrhoea and sometimes constipation (Hundessa and Fufa 2016). *Prosopis* roots have an allopathic chemical effect on other plant species (Elfadl and

Lukkanen 2006). Its foliage is unpalatable to most animals although the seeds are palatable. The tree can be utilised to produce valuable goods, help in soil conservation and in the rehabilitation of degraded saline soils. In its native land in North and South America, *Prosopis julifora* trees have been, and still, are an essential food and help in mitigating climate change effects. However, despite its qualities and uses in its natural range, *Prosopis julifora* becomes a serious invading weed when introduced into non-native areas without proper management (Shiferaw *et al*., 2004). In the USA, Mexico, Saudi Arabia, Kuwait India and South Africa *Prosopis juliflora* pollen has been identified as a major allergen (Killian and McMichael, 2004). Dhyani *et al*. (2008) noted that it has a close allergenic relationship with *Ailanthus excels, Cassia siamea, Salvadora persica, and Phaseolus lunatus* lima bean). On the other hand, some of the plant extracts are used as local medicines, which is a positive contribution.

Prosopis juliflora in Kenya is associated with the reduction of pasturelands and native trees, which are the food source for livestock of agro-pastoralists. In Garissa, 88% of people indicated that *Prosopis juliflora* affected livestock production (Zeila, 2011). In Ethiopia, it was reported that in ten years, 80% losses in livestock and an estimated 85% reduction in milk production could be attributed to *Prosopis julifora* invasion (Tessema, 2012). Tessema also noted that camel ownership dropped by one third in the same county. In extreme cases, people have been compelled to leave their farmlands as a direct consequence of *Prosopi*s *julifora* invasion (Tessema, 2012). The tree grows aggressively and forms thickets that are an ideal breeding ground for mosquitos that transmit malaria, a major killer in some African countries.

In Kenya, 12% of respondents identified *Prosopis juliflora* stands as a refuge for thieves, mainly cattle rustlers (*Choge et al.*, 2006). This is as a result of the impenetrable thickets formed by *Prosopis juliflora* when unmanaged. In Lake Baringo and River Endao, *Prosopis julifora* weed had blocked watering points forcing the residents to move for longer distances in search of water or to access schools and markets (Masakha and Wegulo, 2015). The species has strong thorns which are able to pierce tyres and shoes, thereby causing immense suffering to the communities. It has been alleged by some of the community members that there have been some amputations done as a result of pricking's from the thorns. In addition, the roots make the soil loose, thus unable to hold water (Obiri, 2011).

2.3 Technologies used in control of *Prosopis julifora*

Prosopis was introduced in Kenya for the rehabilitation of degraded drylands. A report by KEFRI and the former Forest Department showed pockets of large-scale colonisation across semi-arid areas of Kenya (Choge *et al.*, 2007). In 2009 the tree had spread and invaded new areas with up to 39 % of land colonised as compared with 5% in 1990 (Muturi *et al.*, 2010). In Baringo, *Prosopis juliflora* was introduced through the efforts of the then Fuel Wood Afforestation Extension Project, a joint FAO/Government of Kenya initiative. This project operated under the former Forest Department in the Ministry of Environment and Natural Resources. They established demonstration plots in 1983 using the local communities under food aid assistance from the World Food Programme. Satellite images of 2012 indicate that *Prosopis juliflora* had spread to 8,555 ha of land, in an area between Lake Bogoria and Lake Baringo in Marigat division, from a meagre 2,906 ha reported in 1998. This constitutes 66% annual spread of *Prosopis julifora* or 403 ha annual increment (Masakha and Wegulo, 2015), making it one of the most invasive plants in Kenya. Some of the methods that have been used to manage the *Prosopis* species include;

Mechanical removal, which is highly labour intensive and creates a significant amount of site disturbance, it can lead to rapid reinvasion if not appropriately handled (Mattrick, 2006). The technology involves root ploughing and chaining using heavy machines. Large trees must first be felled by hand before ploughing the root. Unless uprooted, cutting the tree leads to more vigorous growth as the tree has high coppicing ability.

Chemical control involves the use of herbicides to kill trees whose effectiveness depends upon chemical uptake. The use of herbicides has not been successful in controlling *Prosopis juliflora*, owing to the thick bark and small leaves with a protective layer which results into poor uptake of the chemical (Pasiecznik *et al.*, 2001 and Tessema, *et al.*, 2012). The cost of using chemicals is also very high. Chemicals can affect community health if washed into the water bodies.

Cultural Control is very effective, although its labour intensive and only practical for small landholdings. It can be used in conjunction with mechanical where big trees have to be removed fast. On the other hand, burning kills only young trees and is ineffective for mature trees of *Prosopis* (Berhanu and Tesfaye, 2006). Biological control is where predators or pathogens are used to control invading reproduction (Geesing *et al*., 2004 and Zeila, 2011). Most of the biological control of *Prosopis* has been done in South Africa. *Algarobius*

Prosopis and *Neltumius arizonensis* (both Coleoptera: Chrymelidae: Bruchinae) successfully established themselves in large numbers and have a significant effect on *Prosopis* species.

One of the management tools used in American grassland to control *Prosopis julifora* was fire. It can be used successfully as a management tool for the prevention of reestablishment of young seedlings while also improving forage production. For mature trees, they are protected by thick barks which enable them to sprout rapidly after a fire. Fire has also been used in the integrated *approach* whereby *Prosopis julifora* is sprayed with herbicide to produce deadwood, which is later ignited to prevent sprouting.

In Kenya, utilisation is the preferred *Prosopis julifora* control technique being promoted. Several governmental and non-governmental organisations have been publicising information in this area on how the community can harness benefits from the tree. This initiative is supported by Madumere (2000) and Agbogidi and Ofuoku (2005). The three are of the opinion that effective utilisation of agricultural extension education programs can certainly help in raising awareness among the people. Such initiatives are fundamental in the management and control of the invasive species. In 2005, a project was launched in Baringo County to develop income-generating activities using *Prosopis julifora*. In 2006 a workshop was held in Marigat to demonstrate and discuss *Prosopis julifora* management and utilisation including its use as human food (Choge *et al.*, 2007). These have been followed with other training and field days to demonstrate different management techniques and formation of user groups (i.e. charcoal user group). The government also went ahead and lifted the ban on charcoal production to encourage the community to utilise the species in the hope that it will reduce its invasiveness

In 2004, KEFRI introduced the Farmers Field School (FFS) concept in collaboration with the farmers in an effort to control and manage *Prosopis julifora* invasion (Choge *et al.*, 2006, Njoroge *et al.,* 2012). They trained participants on thinning and pruning of stands, suppression of regeneration and coppicing by uprooting of seedlings and burning of stumps.

In 2014, NEMA gave the go-ahead for the construction of a power plant that would produce electricity using biomass from the tree. The power plant estimated that the *Prosopis julifora* resource could serve it for ten years (Kool *et al., 2014*). The power plant is currently in place though it has not started operations. It has the potential to provide job opportunities and consequently improve livelihoods.

2.4 *Prosopis juliflora* as a resource

The utilisation of natural resources is crucial for local livelihoods and social uplifting in developing countries (Shackleton *et al.,* 2015a and Shackleton *et al.,* 2015). *Prosopis julifora* has a high economic potential that can benefit rural communities and contribute to national development if fully utilised. It can be utilised as a construction material; animal feed; for soil regeneration; firewood; charcoal; as a source of gum, wax and honey, as a medical remedy and as human food. Energy is central to nearly every major challenge and opportunity the world faces according to sustainable development goal no.7. *Prosopis julifora* tree has been able to meet 85% of the firewood demands of the rural people in the Thar Desert of India (Emerton and Howard, 2008) thus contributing to meeting this goal.

In Kenya, most urban households rely on charcoal as an energy source. A national survey was done in 2013 estimated that charcoal consumption increased from 1.6 million t/year in 2004 to 2.3 million t/year in 2013. The sector is now worth Kshate135 billion (Liyama *et al.,* 2014). *P juliflora* produces good quality charcoal with calorific value as high as 7.854Kcal. A study by Chengole *et al.* (2014) recorded that communities living in Baringo earn over 20 million Kshs (US$250,000) each month from the sale of charcoal. This is an excellent incentive to motivate residents to utilise the tree. The fuelwood also burns well with a calorific value of 4.952Kcal when it is wet. It does not spit, spark or emit much smoke, which makes it very good (Oduor and Githiomi, 2013).

Prosopis julifora pods are highly nutritive and are consumed by animals. The pods have a high protein content that improves livestock production and increases the quality of meat and butterfat products (Livingstone *et al.,* 2014). Feeding trial done in India on livestock using rations containing up to 45% of *Prosopis julifora* components yielded 1.5% increase in cattle body weight (Pasiecznik *et al.,* 2001). When crushed, they can be used to make human food. Dried and ground *Prosopis juliflora* pods can be mixed with wheat flour to make *chapatis, mandazis* and cakes. Syomiti *et al.,* (2015) indicated that *Prosopis julifora* pods could increase the earning of the local people with up to 50 US$ per day with only a collection of 150 kg per person per day. While Wise *et al.* (2012) indicated that in South Africa, pods are collected to produce organic medicines (‘manna’) and are said to have properties that stabilises blood sugar levels in humans. The company that produces the medicine makes profits of US$100 000 per annum and has the potential to increase profits 10-fold if the product is marketed internationally In Ethiopia farmers have been able to earn over 15,500 ETB (1,550 US$) from the sale of pods to cooperatives. Goats fed on a mixture of 50%

Prosopis and 50% concentrate corn performed better than those on typical pasture land (Admasu, 2008). *Prosopis juliflora* is also a nitrogen-fixing plant that improves soil nutrient condition and is known to ameliorate saline soils (*Ndhilovu et al*., 2011)

2.5 Perceptions of *Prosopis* species by communities

Diversity in the perception of different communities about *Prosopis juliflora* has been reported globally. This is frequently modelled by the impacts of the plant on their livelihoods as well as micro-economic status. (Sheckeleton 2015). Perceptions on the species can also be strongly influenced by invasion abundance. As the abundance increase, associated costs rise, and benefits fall due to issues such as resource accessibility (Wise *et al.,* 2012) Although *Prosopis* species is frequently associated with invasive alien species, there are positive ecological and socio-economic impacts that have been noted about the species. The positive impacts are evident in areas where the species have been used to stabilize dunes, shade and furniture wood, construction timber, feed and forage and fuelwood among others uses.

A study done in Garrisa by Dubow in 2011 indicated that 92% of the community believed that *Prosopis* was highly invasive and was colonising more land. These were same as one done in South Africa where 98% of the people indicated that they would like to see it eradicated since it was having a negative impact on their livelihood. Factors such as biophysical characteristics, social context of the area and familiarity with the invasive species shape perception. For example, there are two theories that can explain the perception of the socio-economic impacts of *Prosopis*. The first theory states that the perceptions of people about invasive species are shaped by the economic impacts of the species on the livelihood. The second is founded upon the microeconomic theory of consumer preferences. The microeconomic theory indicates that preference over commodities are dictated by the characteristics of the households, including occupation, proximity to forests and users of the invasive species (Pasieznik, 2001)

2.6 Adoption of technology

Technological growth, their improvement and adoption processes are a highly discussed topic in politics, industry and research as a community. Robert *et al*. (2017) predicts that the implementation of technology can support rural development. Use of agricultural technology affects the rate of increase in agricultural output and determines how it impacts on the poverty levels and environmental degradation (Meinzen-Dick *et al.*, 2004). The focus of research has been on developing technologies that can reduce invasion of the *Prosopis*

juliflora. However, the only way farmers can benefit from these research technologies is if they perceive them to be appropriate and proceed to implement them as supported by Meinzen-Dick *et al.* (2004). There are several factors that affect the adoption of technology. However, the decision to adopt is often an investment decision that may depend on the cost of the technology or whether farmers possess the required resources.

Influences on farmers' decision making the process by neighbours successfully implementing new technologies are rated as the main driver for the adoption process (Tessema *et al*. 2016), and it is stated that it is possible to exploit and enhance this mechanism by introducing communities of practice (Dolinska and d'Aquino, 2016). Janvry *et al*. (2016) states that the highly influencing factors are the information about and availability of technology.

Families are viewed as the real decision-making units, and not only considered as opinion sources but as actors in making egalitarian or conjoint decisions through a negotiation process. They act more in investment decisions, capital and occasionally in labour allocation and overall production (Vail, 1981). Factors that affect the level of involvement of the spouse in the decision-making process include interactions between psychological, micro-social, household and macro-social factors. These are individual self-identities, personal resources, family dynamics, the structure of the farm enterprise, the structure of the labour market and the desire of unity and authority on behalf of the family male(.Kabwe 2010)

TAM model developed by Davis is the most used framework in predicting information technology adoption (Paul, John and Pierre, 2003). Lee and Jun (2007). It focuses on the effects of perceptions of the technology's usefulness and convenience on adoption intentions (Luarn and Lin, 2005; Lai and Zainal, 2015). It attempts to help researchers and practitioners to distinguish why a particular technology or system may be acceptable or unacceptable and take up suitable measures by explanation besides providing a prediction.

2.7 Experiences with Forestry Technology Adoptions on farms

In forestry, some of the technologies that have been adopted are agroforestry technologies. These technologies are mostly adopted if they provide multiple benefits to farmers. This is supported by Mohammad (2014) who indicated that farmers were more likely to implement new practices and stick with them, if they see direct economic benefits (increased productivity, better means of processing and storing, and better knowledge of markets and prices). In his research in Tharaka - Nithi County, 13 farmer groups established tree nurseries and had over 6,000 mangoes seedlings of improved varieties. Other examples are the

adoption of soil erosion control, boundary marking, and wood fuel energy, provision of fodder and food, which was highly adopted in Nzoia location (Wafuke, 2012). A study done by Othniel (2016)revealed that there are three factors, namely extension services, agricultural labour force, and seriousness of soil erosion that have a significant positive impact on the adoption of technologies in Kenya. However, in some instances, the income accruing from off-farm activities by farm household members could help farmers afford the cost of implementing technology, thereby increasing the adoption overall. Another study carried out by Mawoli (2016) on the level of adoption of agroforestry technology in Muoni watershed established that adoption of the technologies was at 78.57.

There are many experiences where technologies were adopted during the dissemination of the technologies by research and NGOs, later transpired to be due to temporary influence of the project rather than a sustainable change. For example, a farmer's adoption of improved legume tree fallow in Western Kenya had vanished from the fields of the small farmers, when intensive promotion campaigns stopped (Giller *et al.,* 2009). Another experience from a pilot study involving the International Centre for Research in Agroforestry (ICRAF) and some key national research and development institution showed that village, sub-location committees are often inactive without strong follow up, which is best provided by such local institution as government extension staff close to farmers (Noordin and Jussoff., 2010). These follow-ups play a vital role in scaling up the adoption of agroforest technologies, monitoring, evaluation, and providing feedback to enable sustainability.

Table 1.1: Selected key empirical studies and research gaps

Author/Year	Title of the Study	Summary of main findings	Gaps identified
Esther Mwangi and Bret Swallow 2005	Invasion of *Prosopis juliflora* and local livelihoods: a case study for Baringo	*Prosopis* is a valuable resource for dryland and that efforts to management are expensive	Though the study assessed a wide range of parameters it did not assess the rate of adoption that could determine its control
Shackleton *et al.*, 2015	Stakeholder perception and practices regarding *Prosopis* (Mesquite) invasion and management in South Africa	Perception, Knowledge and practices relating to *Prosopis* differed between stakeholders and were linked to the social context of the stakeholder groups	The study focused on knowledge of the species and how it affected the perception of stakeholders but did not investigate the factors that influence management/control of the species
Wakie *et al*.,2016	Is control through Utilization of a cost-effective *Prosopis juliflora* management strategy	Control through utilisation may be a viable *Prosopis juliflora* management strategy under the right environment settings	The stud focused on the benefits of *Prosopis julifora* but did not focus on the factors affecting the adoption of utilisation as a control method
Abdulahi et al., 2017	Distribution, impacts and available control methods in Ethiopia	The effects on the environment and human livelihoods are escalating rapidly from time to time, and there is a need to diversify more effectively management approaches to drastically reduce adverse impacts and enhance benefits	The study focused on management technologies and the effects on the species but did not investigate the factors that are influencing the adoption of these technologies for improved livelihoods

2.7 Theoretical framework

Several types of models can explain the adoption decisions of new technologies. Most of them have related various independent variables to innovativeness. These technologies have also correlated dependent variables such as economic status, personal variables and communication behaviour to innovativeness. The one that has been widely used to identify factors that influence decisions to adopt or reject technologies is the Technology Acceptance Model (TAM). It highlights potential design issues before users of the technology interact with the system (Dilton and Morris 1996, Mohd Ahman, *et, al* 2011). TAM demonstrates pioneering research efforts by generating a framework for explaining behavioral intentions

and the actual behavior of users of new technology. Perceived usefulness (PU) and Perceived Ease of Use (PEOU) are the perceptions of the belief users hold about the system (Dilton and Morris 1996). PU is the degree to which a person believes that using a particular system would enhance his or her job performance and PEOU is the degree to which a person believes that using a particular system would be free of effort. Rogers 2003 postulated that adoption occurs when one has decided to make full use of the new technology, as the best course of action for addressing a need. Adoption is also reached after a sequential five-step, time-ordered, innovation-decision process. This is supported by Thangata and Alavalapati (2003) who added more variables into the list, including perceived attributes of the innovation; type of innovation-decision; communication channel; nature of the social system; and the extent of change agent promotion efforts. Other variables that affect adoption also include socio-economic and demographic variables, including income, educational level, farm size, gender, age, family size and size of the family farm.

The researcher, therefore, adapted the TAM model but also made references to studies conducted by other scholars such as Oliveira and Martins (2011) on improved agricultural technologies in Kenya and elsewhere to gain insights on levels of adoption and influencing factors. This study assumed that management technologies of *Prosopis juliflora* that have been developed by the government through KEFRI and disseminated in collaboration with other organizations in Baringo would reduce its invasibility and generate ecological and socio-economic benefits.

2.8 Conceptual framework

Figure 2 illustrates the conceptual framework of the study, with the arrowheads pointing out the existing influences between relevant variables.

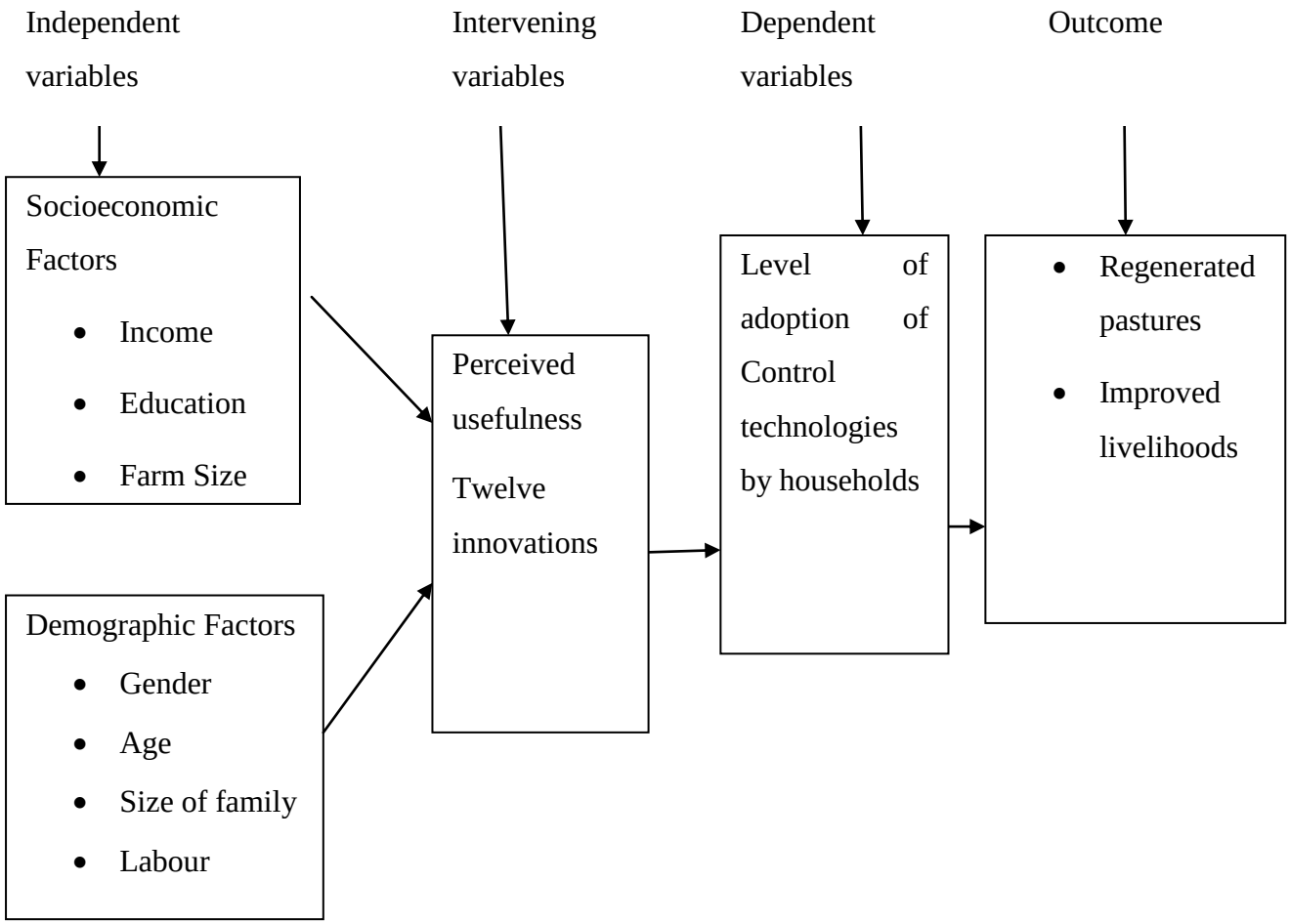

Figure 1.2: Conceptual Framework, Modified from Davis (1989)

The basic concept of the study suggested that socioeconomic factors (namely, household income, education, and household farm size), and demographic factors (namely, gender, age, family size, and size of family labour) will influence the adoption and utilisation of *Prosopis julifora* control innovations. The adoption and utilisation of *Prosopis julifora* control innovations will, in turn, influence the degree of control of *Prosopis julifora*, which in turn will influence the regeneration of pastures and improved livelihood accruing from the control of *Prosopis julifora*. The conceptual framework corresponds and is in line with the questions of the study, which will be tested using regression analyses.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study area

3.1.1 Description of the study site

This study was undertaken in Marigat Division in Baringo County, Kenya. It is one of the fourteen administrative divisions in the county. The county is located between latitudes $0^{o}12'$ and $1^{o}36'$ N and longitudes $35^{o}36'$ and $36^{o}30'$ East (Magut *et al.*, 2015). The study area ranges between 900 and 1200 m above sea level and is generally hot and dry throughout the year (Saina *et al.*, 2012). The annual and inter-annual precipitations are highly variable with annual precipitation of 650mm (Magut *et al.*, 2015).

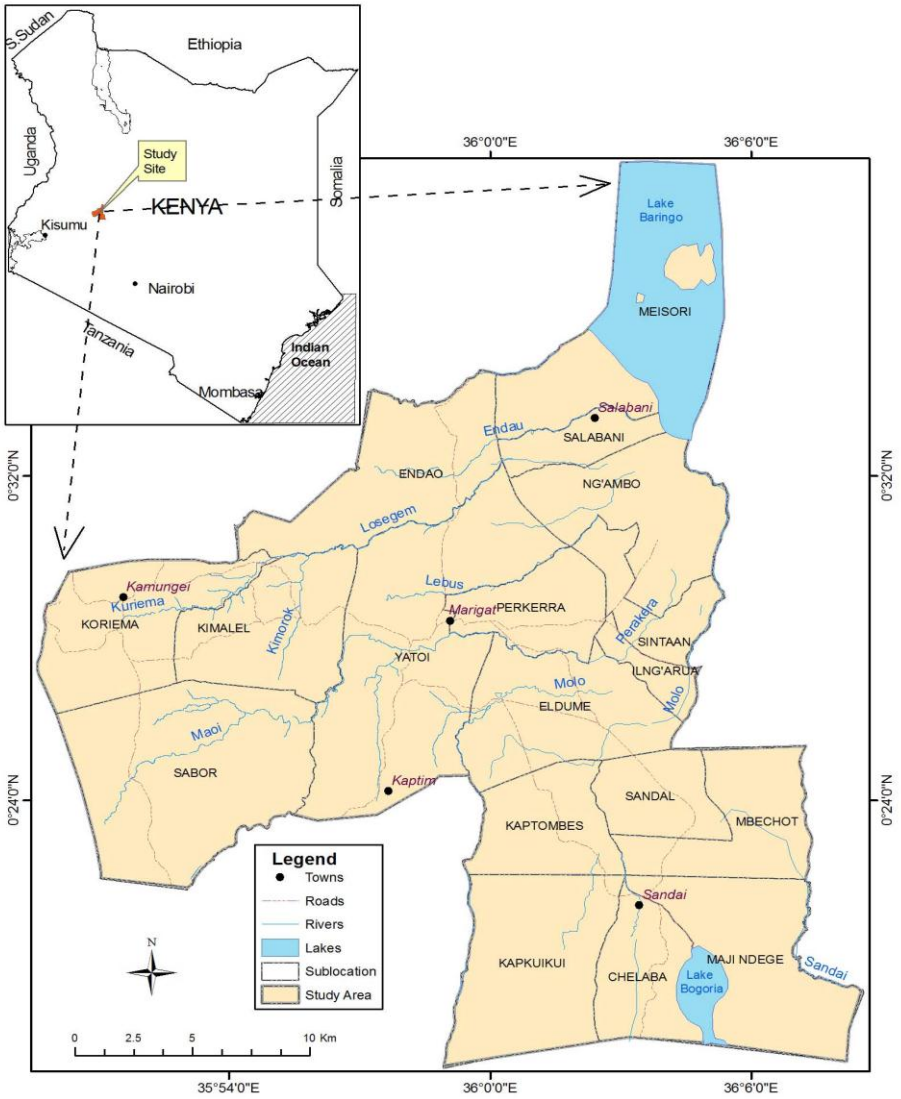

Figure 3.1: Map of study area

3.1.2 Land use and settlement history

The area is inhabited by three principal ethnic groups; Tugen, Pokot, and Njemps, also known as IIChamus. The land is communally held under common property regime in the Njemps flats. However, land privatisation has been going on in some trading centres occupied by the agro-pastoral communities. The Njemps are sedentary agro-pastoralists but were originally hunters and gatherers. They live to the south-west around Lake Baringo. Tugens are agro-pastoralists who cultivate crops and also keep livestock, mainly cattle sheep and goats. While the Pokots are nomadic to semi-nomadic pastoralists, herding large heard of cattle, sheep, goats and camels (Meyhoff, 1991). Apart from the activities stated, land use is slowly changing as part of the land is now used for modernity, such as the building of schools, hospitals and roads. Some of the areas inhabited by people are also being used for various types of tourism, and this is evidenced by the hotels that are to be found around Marigat town. These hotels serve both local and non-local tourists.

3.1.3 Physiography, geology and soils

The sub County can be divided into highland and low lands with the former having well-drained soil that is suitable for agriculture and growth of *Prosopis julifora* weed, though susceptible to soil erosion. Lowlands feature complex soils with varying texture and drainage conditions that have developed alluvial deposits, while some are saline. The alluvial deposits are derived from the tertiary and quaternary pyroclastic and volcanic rock sediments weathered from uplands and deposited to the area through erosion (Mwangi and Swallow, 2005). A larger area is characterised by shallow stony soils with rock outcrops and lava borders (GoK, 2010).

Soils within the plain are well-drained, deep, friable silty loams or heavy cracking clays with potential for irrigation. Major topographical features are rivers, valleys plains and the floor of the Rift valley.

3.1.4 Climate

Marigat Sub County is one of the arid and semi-arid regions of Baringo County. The rainfall variability is high with one rainy season from April to August, followed with a prolonged dry period. Rainfall patterns are strongly influenced by local topography, and long-term average annual rainfall ranges from 600mm in the lowland of Njemps plains to 1000-1500mm in the high lands. The average minimum and maximum temperatures are 20^{o}C and 30^{o}C, respectively. Temperatures can sometimes rise to 37^{0} C in some months, while the hottest

period is between January and March. Recent climatic events in Kenya, indicate that these areas are affected by climate variability. The role of vegetation is thus important to maintain some normality.

3.1.5 Vegetation composition and biodiversity

The vegetation assemblages include Acacia woodland along major rivers, *Balanites aegyptica* and bushes of *Salvadora persica*. These slowly give way to seasonally flooded grasslands and scrublands towards the uplands in the North, western and southern parts of the area. Ephemerals dominate the understory, the open and bare areas. Due to land degradation, herbaceous vegetation is almost non-existent, except areas enclosed for the rehabilitation of degraded rangeland. *Prosopis juliflora* has invaded most of the areas forming thickets, thereby inhibiting undergrowth.

3.1.6 Economic activities in the study area

Livestock keeping is the primary economic activity and provides 90% employment of the population (RoK, 2012). The poverty level of Baringo County is estimated at 58.5% and is reported to be more in the rural areas where income-earning activities are not diversified. Most of the labour force in the county is unskilled and semi-skilled with the income being derived from sales of livestock and agricultural products. However, the activities are slowly changing as residents adopt some forms of modern life. Small enterprises are thus slowly being developed in some areas.

3.2 Research design and survey

This study employed a socio-ecological survey involving interviews for data collection through the use of semi-structured questionnaires with both close-ended and open-ended questions. The data collection process involved the gathering of the data required to measure the variables constituting the study objectives as described by (Sapsford and Jupp, 2006). Survey instruments used included a semi-structured questionnaire and interviews that comprised of probing questions to the respondent's information. Focus Group Discussions were correspondingly included. This method was found to be appropriate because the data that was collected composed of self-declared responses of the heads of households. The data was collected during the months of March to May 2017, using a set of questionnaires (Appendix 2).

3.3 Study population and sampling unit

3.3.1 Sampling frame

According to the 2009 population and Housing Census (KNBS, 2010), Marigat Sub- County has a total of 9,160 households. The study population in the three selected locations selected (Marigat, Mochongoi and Baringo south) totalled to 3,242 households. Study villages in all the 3 locations were randomly selected from the list of villages provided by the local chiefs and the village elders. The household list from sampled villages was compiled by household names. The list of households in each location was then taken as the sampling frame.

3.3.2 Sample size

The sample was determined using the Mugenda and Mugenda, (1999) formula, and calculated as follows:

$$n_o = \frac{Z_{\alpha/2}\, p(1-p)}{d^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Where n = sample size,

p = estimated population proportion of farmers who have adopted *Prosopis juliflora* utilisation techniques introduced by the government and other organisation and

d = the absolute precision defined and SE is the standard error.

$$d = Z_{\alpha/2} SE$$

Where SE is the standard error; and the taking $\alpha = 0.05$, estimated the population proportion of farmers adopting the intervention techniques as = 0.09, absolute precision d = 0.03, the sample size is calculated as given below.

Z= the normal standard deviation, set at 1.96 which corresponds to 95% confidence level

According to Mugenda and Mugenda (1999), the value of p should be determined on a pilot survey, and when it is not available, a 50% maximum variability is assumed

$$n_o = \frac{1.96^2\ 0.09(0.91)}{0.03^2} = 349.5856 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Moreover, since the sampling was from a finite population of size N = 9,160 (Total number of Households in Marigat according to the 2009 population census), then

$$n = \frac{no}{1 + (\frac{no}{N})} = \frac{349.5856}{1 + (\frac{349.5856}{9{,}160})} = 336.73 \ = 337 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

Three hundred thirty-seven respondents represented the sample for this study.

3.3.3 Sampling procedure

Simple random sampling technique was used; the technique ensures that all the household heads in Marigat sub-County are selected by chance. It also ensures that all the subjects in the population from which the study sample was drawn had an equal chance of selection (Sharma, 2005).

The names of the household heads in the sub-locations were given by the chiefs. They were then written on pieces of paper and put in a basket. One paper at a time was randomly drawn and recorded without replacement until the desired number of respondents allocated proportionally in each location was achieved. The drawn pieces of paper with the names of the household heads formed the sample in each sub-location.

3.4 Data collection

3.4.1 Household surveys

The study employed a descriptive survey design involving interviews for data collection through the use of semi-structured questionnaires with both close-ended and open-ended questions. The household survey was used to obtain socio-economic and demographic data (Education level of respondents, age, gender, household income, and number of households, land size, members of the household and household size.

3.4.2 Focus group discussion

Purposive sampling was used to select the people who formed the group. Twelve people were selected, mainly opinion leaders from the group. They included Chiefs, Forester, Community Forest Associations (CFA) and community-based organisations (CBO) leaders, and Agriculture extension officers. The method was used to provide detailed information on the community's uptake of *Prosopis juliflora* management. Only one focused group was used with the aim of corroborating information that was obtained from households.

3.5 Definition of study variables

There were several study variables that were used they included: Socio-economic characteristics that are household income, household level of education, farm size. The demographic ones are gender, age, family size, and available family labour.

The following variables constituted the study objectives; the five research questions were defined and measured as follow**:**

3.5.1 Socio-economic factors

Socioeconomic refers to society related to economic factors. These factors relate to and influence one another. These were head of household's (respondent's) personal social and economic characteristics, including household income, household level of education, and farm size. These were defined and measured as follows:

Household income-was the total household income (for all earning members of the household) per year from farm income, off-farm income and remittances.

It was measured in Kenya Shillings per year.

Level of education_was the head of household's (respondent's) highest level of formal education

It was measured in categories and scored as:

0 No formal education
1 Primary level
2 Secondary level
3 College level

Farm size: was the area spread or the acreage of the household farm used for cultivation and other agricultural and natural resources activities for livelihood and income generation. It was measured in hectares.

3.5.2 Demographic factors

These were the head of household's (respondent's) personal population and growth characteristics (vital statistics), including household gender, age, family size, and available family labour.

These were defined and measured as follows:

Gender- sex of the heads of households (respondents), and was measured as “male” or “female”.

Age- life span lived by the respondents, and was measured by the number of years lived so far.

Family size- number of kinship members living together and dependent on the family farmland. It was measured by the number of people residing in the household, including the head of the household.

Size of family labour- number of family kinship members residing in the household and involved in household farming and other productive and income-generating activities of the households.

It was measured by a number of available workforces providing labour for farming and other productive and income-generating activities of the households.

3.5.3 Intervening variables

Intervening variables are variables that explain the relationship between two other variables, usually the independent variable, which is the variable the researcher controls and the dependent (outcome) variable which is the variable that is observed based on the changes in the independent variable. In this study, the intervening variables were the management innovations that were being used and the % of reduced *Prosopis julifora* cover.

Table 3.1: Adoption and utilisation of the *Prosopis julifora* control methods

No	Act/Usage	Expected Output
1	Turning the *Prosopis julifora* tree into charcoal	Economic benefit
2	Extracting good timber for parquet floors, furniture, posts, fuelwood	Socio-economic benefit
3	Making household fencing	Ecological benefit
4	Preparation of the bark for turning and for roofing	Socio-economic benefit
5	Making gum from the tree to form adhesive mucilage	Economic benefit
6	Selecting appropriate vegetative parts of the tree to provide fodder for small stock.	Economic benefit
7	Learning and providing proper management of the tree	Ecological benefit
8	Establishing and sustaining bee pasturage in the household farm	High honey production(socio-economic benefit)
9	Commercialising the tree products for household use	Socio-economic improvement
10	The uprooting of seedling and burning of stumps	Suppressing regeneration and coppicing (Ecological benefit)
11	Thinning and pruning	Ecological benefit (regrowth of ground vegetation)
12	Providing biomass to the power plant	Electricity production

These were household adoption and use of the *Prosopis* control innovations in the last ten years.

Adoption and utilisation of the control innovations were measured by the number of innovations adopted and used in the last ten years.

3.5.4 Degree of *Prosopis julifora* control in the household farms:

This was the extent of reduction of the *Prosopis julifora* in the household farm, as a result of the use of any of the thirteen (13) innovations listed above, that were intended for control of *Prosopis* spread and invasion.

This was measured by the per cent (%) of *Prosopis julifora* reduced cover in the household farm, relative to original status.

3.5.5 Degree of benefits accrued from the control of *Prosopis julifora*

These were the regenerated pasture and improved livelihoods that households had realised in the last two years from the adoption and utilisation of the control innovations, which resulted from the control of the *Prosopis julifora*. The ecological benefits were measured as environmental health of the household farm, as indicated by the extent of regenerated pastures and desirable plant species, expressed in per cent (%) of the household farm. The improved livelihoods were measured as financial gains accruing through sales and commercialisation of *Prosopis julifora* and products from the household farm, measured in Kenya Shillings.

3.6 Data analysis

The quantitative data were analysed using both descriptive and inferential statistics. The descriptive statistics were used to describe and summarise the data in the form of graphs, tables, frequencies and percentages. The inferential statistics were mainly focused on the chi-square analysis, regression and correlation analysis - Pearson Moment Correlation analysis which was used to explore the relationship between various socioeconomic and demographic factors influencing the adoption of *Prosopis juliflora* control innovations in Marigat. The respondents were drawn from Marigat Division in Baringo County, Kenya

Table 3.2: Operationalization of study variables

The following variables constituted the study objectives

Objective	Variable	Indicators	Measurements	Measurement Scales	Type of Analysis
To determine the socioeconomic and demographic factors that influence the adoption and utilisation of *Prosopis juliflora* among the households in Marigat, Baringo County	Socio-economic factors	▪ Household income ▪ Level of education ▪ Farm size	▪ Amount in Kshs. ▪ Level of education [0-No formal education, 1-Primary level, 2-Secondary level, 3-Tertiary Level] ▪ Total land in acres	Interval Interval Nominal	Descriptive Correlation Chi-square tests, Cross tabulation,
	Demographic factors	▪ Gender ▪ Age ▪ Family size ▪ Size of labour	▪ Either male or female ▪ No. of years since the birth ▪ Total number of persons ▪ The number involved in the farming	Interval Nominal Nominal Nominal	Descriptive Correlation Chi-square tests
To determine the types of *Prosopis juliflora* control innovations adopted, and the degree of their utilisation among households in Marigat, Baringo County	Intervening variables	▪ Degree/Level of Adoption and utilisation derived from control of *Prosopis juliflora*	▪ Number of techniques adopted by the respondents under various derived utilisation	Ordinal	Descriptive Correlation Regression Cross tabulation
Determine the influence on adoption and utilisation of *Prosopis juliflora* among the households in Marigat, Baringo County	Dependent Variable	▪ Adoption and utilisation levels of control innovations	▪ Burning charcoal ▪ Timber ▪ Fencing ▪ Bark for turning and for roofing ▪ Gum adhesive mucilage ▪ Fodder for small stock. ▪ Good management of the tree ▪ Bee pasturage in the household farm ▪ Commercialising the tree product for household ▪ The uprooting of seedling and burning of stumps ▪ Thinning and pruning ▪ Biomass to the power plant	Interval	Descriptive Correlation Chi-square tests, Cross tabulation

CHAPTER FOUR

RESULTS

4.1 Socio-economic and demographic characteristics

The gender distribution of household heads showed that 71.5% were males, while 28.5% were females. The overall average household was composed of five members (5.26±0.14) and the mean age of household head of 40.00±0.66.

Table 4.1: Comparison of Socio-economic and Demographic Characteristics among the three Locations

	Location						Total	
	Marigat		Mochongoi		Baringo South			
	N	%	N	%	N	%	N	%
Gender of household head (%)								
Female	50	31.6	8	16.7	38	29.0	96	28.5
Male	108	68.4	40	83.3	93	71.0	241	71.5
Age of HH Head	39.29± 0.92		40.06 ±1.99		40.84±1.05		40.00±0.66	
Age categories N (%)								
18-24 years	14	8.9	6	12.5	7	5.3	27	8.0
25-35 years	59	37.3	14	29.2	42	32.1	115	34.1
36-45 years	34	21.5	11	22.9	42	32.1	87	25.8
46-60 years	45	28.5	15	31.3	33	25.2	93	27.6
60+	6	3.8	2	4.2	7	5.3	15	4.5
HH size-Mean	4.98±0.19		6.00±0.47		5.33±0.21		5.26±0.14	
Household categories N(%)								
0-3	53	33.5	11	22.9	32	24.4	96	28.5
4-6	62	117.0	25	52.1	66	50.4	153	45.4
7-9	35	56.5	7	14.6	25	19.1	67	19.9
10-12	5	14.3	3	6.3	6	4.6	14	4.2
12+	3	60.0	2	4.2	2	1.5	7	2.1
The education level of household head (%)								
Primary	54.5		41.7		39.2		46.7	157
Secondary	21.8		39.6		40.8		31.7	106
Tertiary	5.1		0		5.4		4.5	16
Informal education	18.6		18.8		14.6		17.1	58
Occupation of household head (%)								
Salaried employment	9.3		10.4		13.8		11.1	
Work on the Farm	4.3		8.3		1.5		3.8	
Casual labour	16.7		25		16		17.6	
Self-employed business	12.3		0		0		5.9	
Forest products	11.7		0		1.5		6.2	
Agro/ pastoralist	45.7		56.3		67.2		55.4	
Land Size (Acres)	**4.71**±0.38		**3.06**±0.54		**5.43**±0.24		4.75±0.22	
Labour	3.66±0.147		4.65±0.415		4.03±0.194		3.94±0.119	

Source: Survey data (2017)

The majority of the respondents are agro/pastoralist (55.4%) and causal labourers (17.6%), the average land size of 4.75±0.22 acres.

Results on the highest educational level attained by heads of households revealed that 46.7% have at least primary level of education, while 31.7% have attained a secondary level of education and only 4.5% have completed tertiary education with the lowest with 17.1 % having an informal education.

4.2 *Prosopis Juliflora* control innovations adopted, and extent of utilisation

The results indicate that 99% of the sample population were aware of *Prosopis juliflora,* and 36.5% of the respondents were low adopters and utilizers of control techniques of *Prosopis juliflora* as indicated in the table below.

Table 4.2: Adoption of techniques levels

	Frequency	Percent (%)
High (8 to 10 techniques adopted and used)	72	21.36
Moderate d (4 to 7 techniques adopted and used)	112	33.23
Low (1 to 3 techniques adopted and used)	123	36.50
No utilisation (0 techniques adopted and used)	30	8.90
Total	337	100.00

Source: Survey data (2017)

The majority who were 99.7% of the respondents indicated that *Prosopis juliflora* grows freely in their area of residence while only 0.3% were not aware that it grows freely in the area. It is likely to be inferred that people who know about the tress can quickly adopt utilisation methods.

Table 4.3: Knowledge of the presence of *Prosopis juliflora in the locality*

Does it grow in your area	No of respondents	Per cent (%)
No	1	0.30
Yes	336	99.70
Total	**337**	**100.00**

Source: Survey data (2017)

4.2 The Socio-economic factors influencing the adoption and utilisation of *Prosopis juliflora*

4.3.1 Education level of the respondents

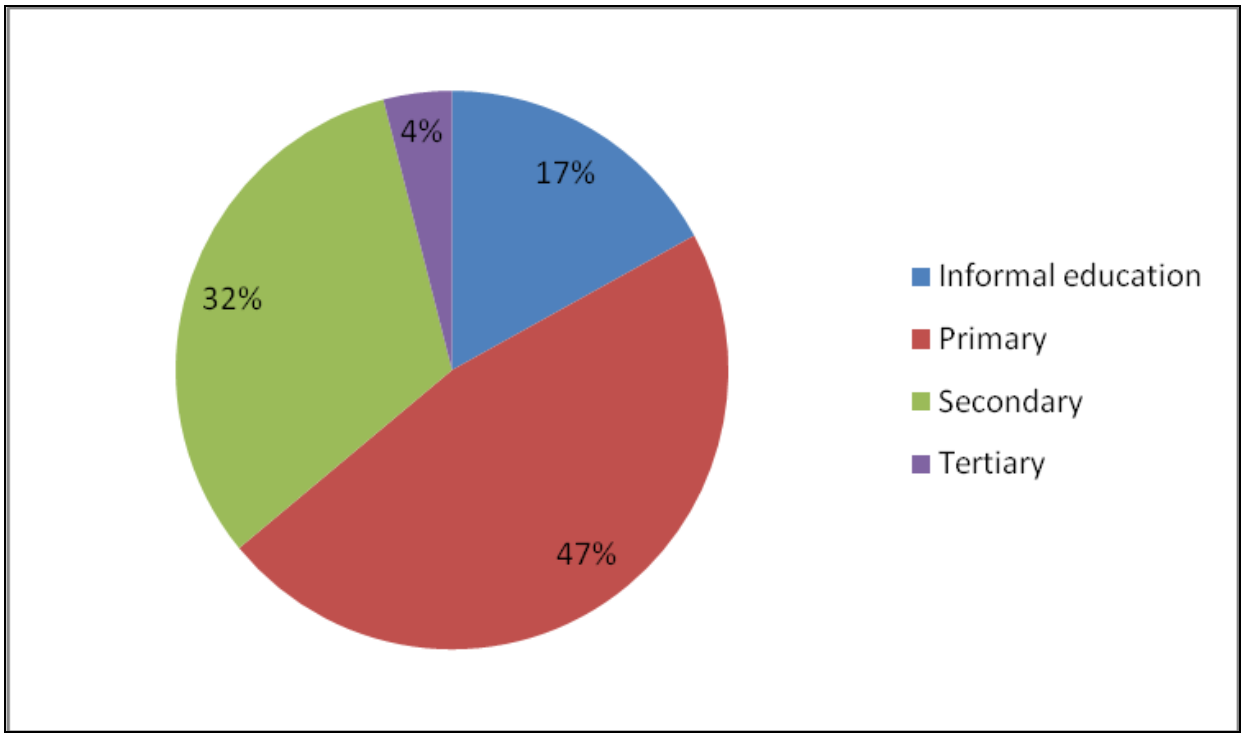

Figure 4.1: Education level of the respondents

The results showed that 17.21% of the respondents are illiterate, and 82.79% were literate, with 46.49% having primary education, 31.45% secondary education and 4.74% having attained tertiary education.

The majority of those who adopted 8 out of 10 techniques were having primary education, while moderate degree adopters majorly had secondary education, most of low adopters and non-adopters were having primary education. Since the p-value is greater than 0.311>0.05; hence, no association was found between the education of household head and adoption of techniques of the utilization of *Prosopis juliflora.*

Table 4.4: Cross-tabulation of adoption of techniques levels vs education levels

	Education levels % (N)				
Adoption of intervention techniques levels	**Informal education**	**Primary**	**Secondary**	**Tertiary**	**Total**
High degree (8 to 10 techniques adopted and used)	16.30 (15)	45.65(42)	32.61(30)	5.43(5)	100(92)
Low degree (1 to 3 techniques adopted and used)	18.18(19)	46.46(49)	32.32(32)	3.03(3)	100(103)
Moderate degree (4 to 7 techniques adopted and used)	18.46(24)	43.08(56)	33.08(43)	5.38(7)	100(130)
No utilization (0 techniques adopted and used)	8.33(1)	75(9)	8.33(1)	8.33(1)	100(12)
Grand Total	**17.51(59)**	**46.29(156)**	**31.45(106)**	**4.75(16)**	**100(337)**
Tests statistics	Chi-Square= 10.51, df=9, p-value= 0.311				

Source: Survey data (2017)

Since the p-value is greater than 0.311 > 0.05; hence, no association was found between the education of household head and adoption of techniques of the utilization of *Prosopis juliflora*.

4.3.2 Land size of the respondents

The mean size of household acres is indicated 4.57±0.181 (SD=3.313) within the study area with the minimum land size being 1 acre and the maximum 30 acres. It is evident that 12.17% of respondents owned land above 7-10 acres while 34.72% owned land between 4-6 acres, and 5.34% having land 10+ acres with the majority 47.78% of the respondents having land between 0-3 acres.

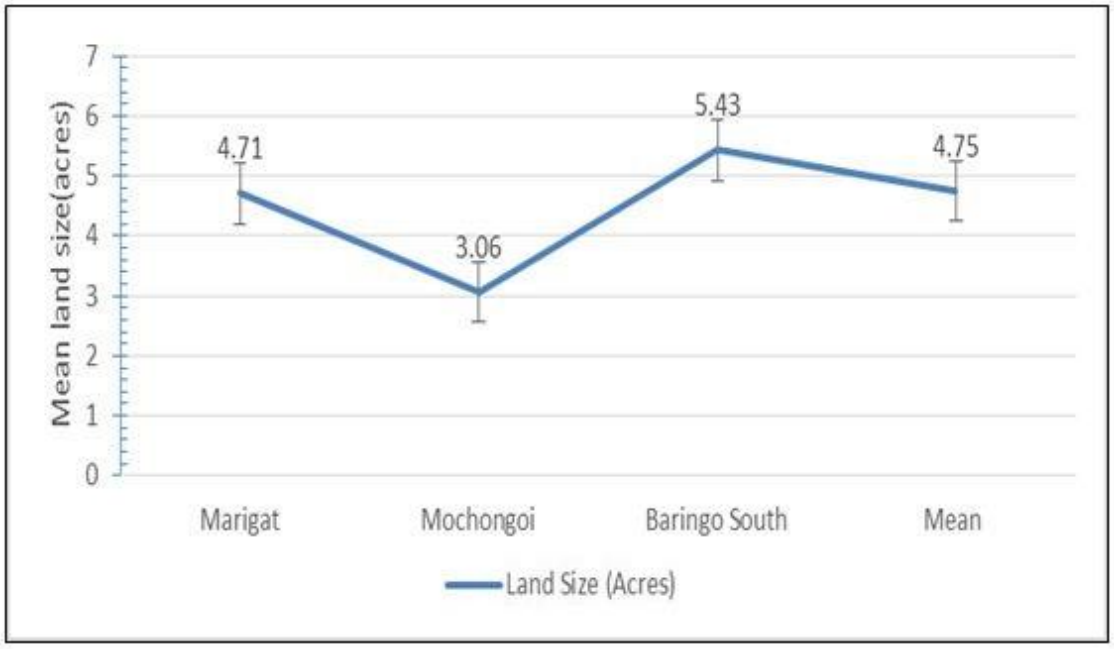

Figure 4.2: Land size per sub-County

The results further show that almost all of the respondents accounting for about 98.2% owned a piece of farming land, while only 1.8% did not own farming land. The p-values less than 0.05 indicate the land size is a significant factor in the adoption of *Prosopis juliflora* control innovations.

Table 4.6: Cross-tabulation of adoption of techniques levels vs land sizes

	0-3 Acres	**4-6 Acres**	**7-10 Acres**	**10 +acres**	**Total**
Adoption of intervention techniques levels	**% (N)**	**% (N)**	**% (N)**	**% (N)**	**% (N)**
High degree (8 to 10 techniques adopted and used)	53.76 (50)	31.18(29)	8.60 (8)	6.45(6)	100(93)
Low degree (1 to 3 techniques adopted and used)	29.41(30)	46.08(47)	20.59(21)	3.92(4)	100(102)
Moderate degree (4 to 7 techniques adopted and used)	60.00(78)	27.69(36)	6.15(8)	6.15(8)	100(130)
No utilization (0 techniques adopted and used)	41.67(5)	33.33(4)	25(3)	0(0)	100(12)
Total	**48.37(163)**	**34.42(116)**	**11.87(40)**	**5.341(18)**	**100(337)**
Test statistics	χ^2=43.82, p=0.001<0.05				

Source: Survey data (2017)

4.3.3 Income from *Prosopis juliflora*

The income was a factor that influences the level of *Prosopis juliflora* adoption and utilisation of techniques; the chi-square results indicate that there is an association between the income from the sale of *Prosopis* products and the level of adoption and utilisation of techniques (χ^2= 22.76, df=9, p-value= 0.006<0.05)

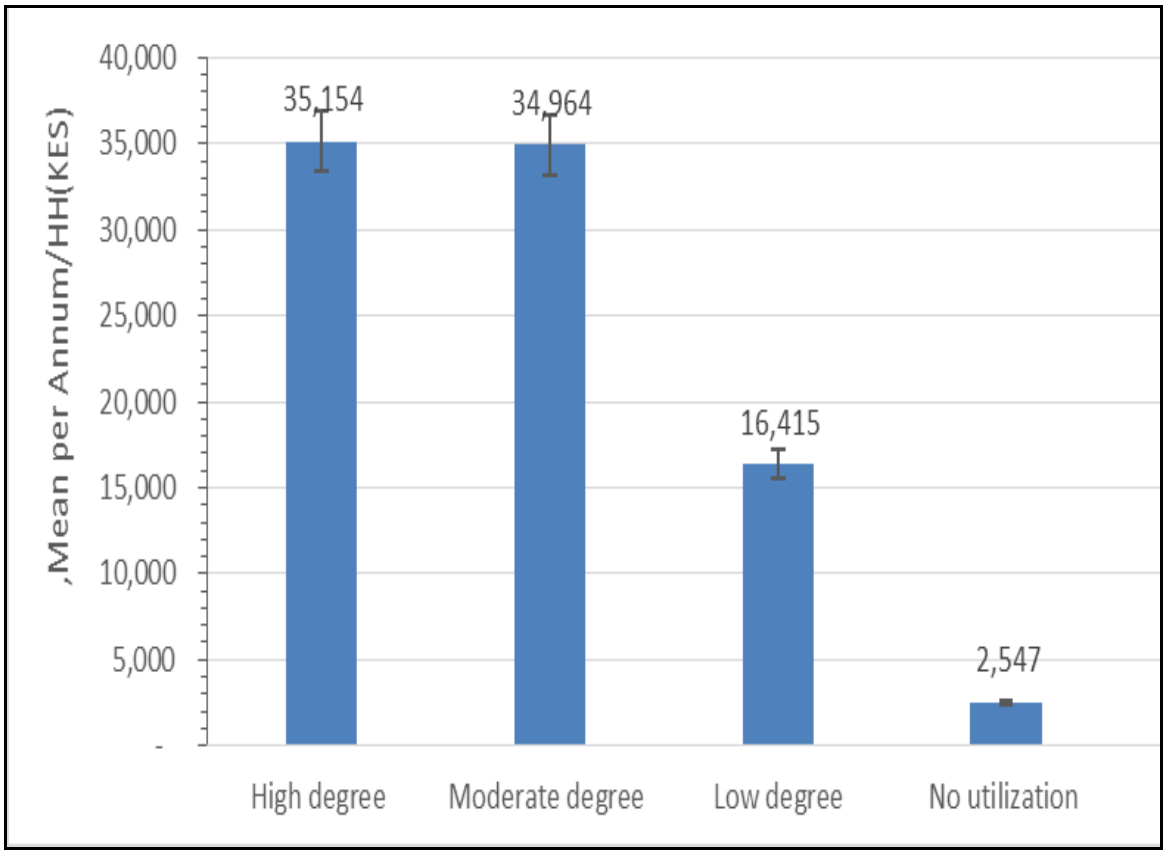

Figure 4.3: Income per household per year

4.3 The Demographic factors that influence the adoption and utilisation of *Prosopis*

4.4.1 Gender respondents

The results revealed that there were more males than female respondents; the female respondents constitute 28.5%, and the male was 71.5%.

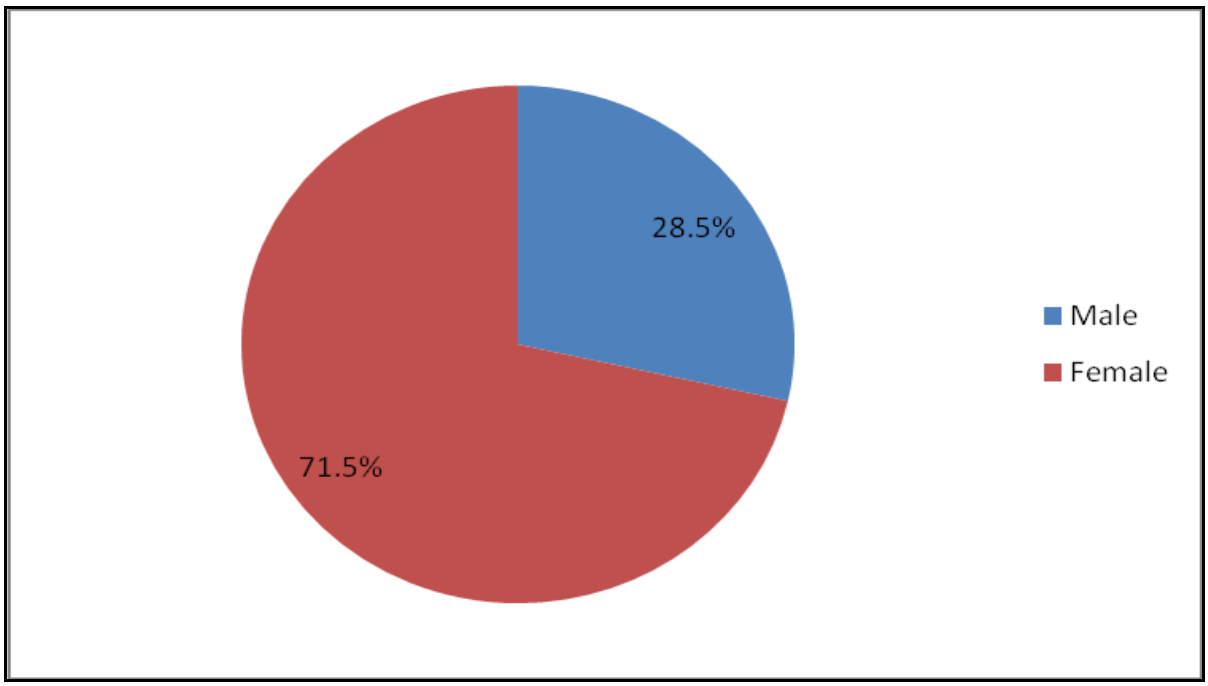

Figure 4.4: Gender of the respondents

There was a statistical association (p=0.01< 0.05) between gender of the household's head and adoption and utilisation of techniques for utilisation of *Prosopis juliflora*. The finding suggests that males headed households were adopters of techniques at all levels of adoptions as compared to their female counterparts; male household heads were more likely to adopt utilisation techniques than females. This can be attributed to the fact that in the community, there is a differentiation of roles and responsibilities. Women responsibilities are mainly domestic (taking care of children), and therefore, men are able to have access to information more than them. Hence, gender is a factor that influences the level of *Prosopis juliflora* adoption and utilisation of techniques. The following pairs of variables have p - values (0.01< 0.05) and a weak negative correlation (r = -0.139) between the adoption of intervention and gender.

Table 4.7: Adoption of intervention techniques levels

	Female	Male	Test statistics
High degree (8 to 10 techniques adopted and used)	8.93%	91.07%	(χ2= 8.680, df = 3, p-value= 0.01)
Low degree (1 to 3 techniques adopted and used)	26.44%	73.56%	
Moderate degree (4 to 7 techniques adopted and used)	28.43%	71.57%	
Grand Total	23.14%	76.86%	

Source: Survey data (2017)

4.4.2 Length of stay and age

The average number of years that the household heads lived in the area was 40±0.66 years with a standard deviation of 12.18. The minimum years that the household heads had lived in the area were 21, and the maximum was 80 years. The majority of respondents (34%) were between the ages of 25- 35, with 8% and 4.7% falling between ages 18 – 24 years and over 60 years respectively. The result further shows that the mean age for age 18-24 years is 23.07 (SD=0.92), 25-35 years is 29.7826 (SD=3.13), 36-45 years' category is 40.48 (SD=2.46), 46-60 years is 52.38 (SD=4.35) and 60+ years had a mean age of 67.63(6.03).

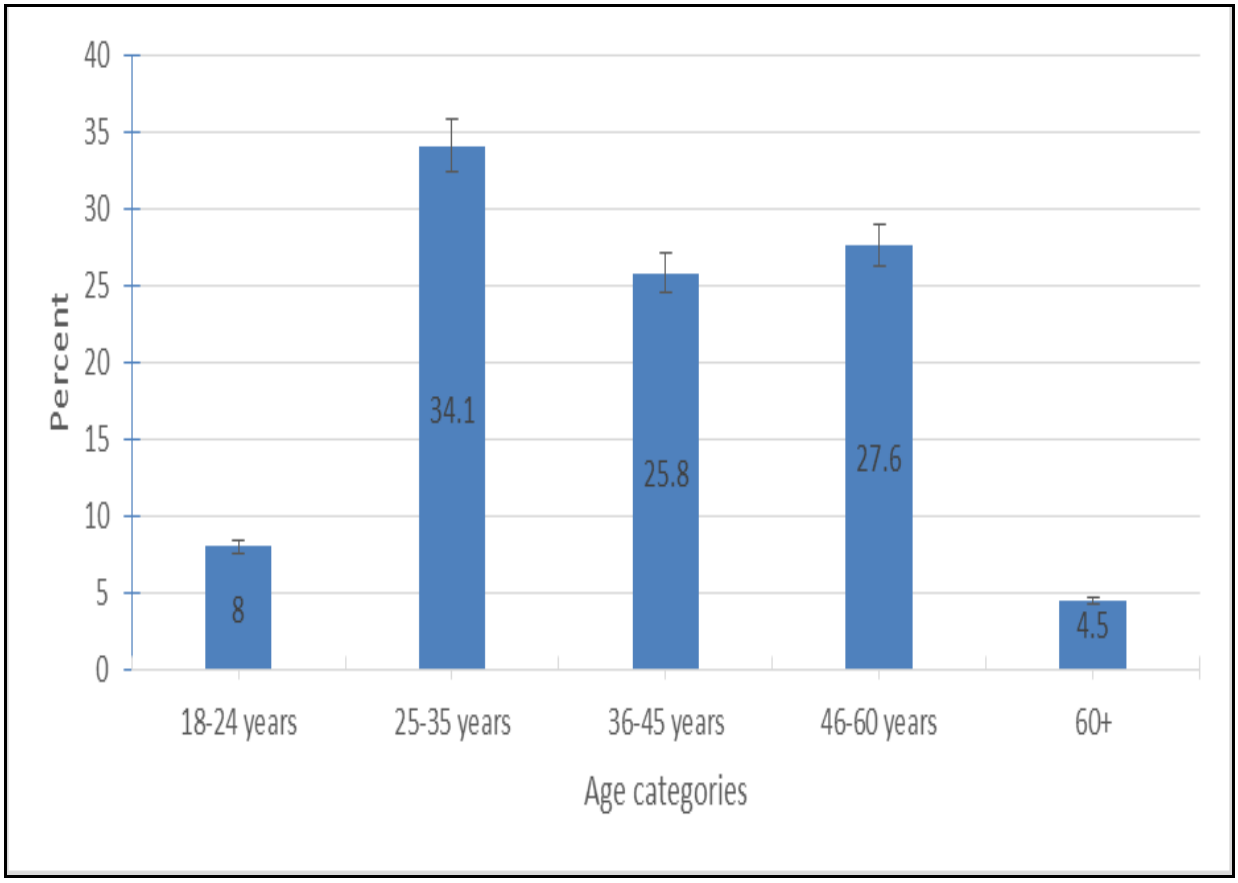

Figure 4.5: Age categories of respondents

The age of household head was positive and statistically significant (p =0.04<0.5) to the adoption of *Prosopis julifora* control techniques. The analysis revealed that the age of the respondents is a significant factor that influences the adoption and utilisation of *Prosopis juliflora*. The study shows that a small proportion of the respondents were below the age bracket of 25 years (Table 2) with an overall mean age of 23.07 years (SD = 0.916). The simple regression analysis conducted for the levels of adoption of techniques and age of the household head to test the relationships between the variables.

The survey result shows that the age of the respondent had a negative relation (coefficient =-0.03) and was a significant ($p \leq 0.010 < 0.05$) determinant of adoption levels of technologies of *Prosopis juliflora* utilisation.

Table 4.8: Age groups of the respondents

	Mean Age of HH Head
High degree (8 to 10 techniques adopted and used)	36
Moderate degree (4 to 7 techniques adopted and used)	39
Low degree (1 to 3 techniques adopted and used)	43
Test statistics of age categories $\chi 2=20.88$, df=8, $p = 0.04 < 0.05$).	

Source: Survey data (2017)

4.4.3 Household size

The mean household size of the majority of the households is 5.26. This is a representation of a moderate household size in this area.

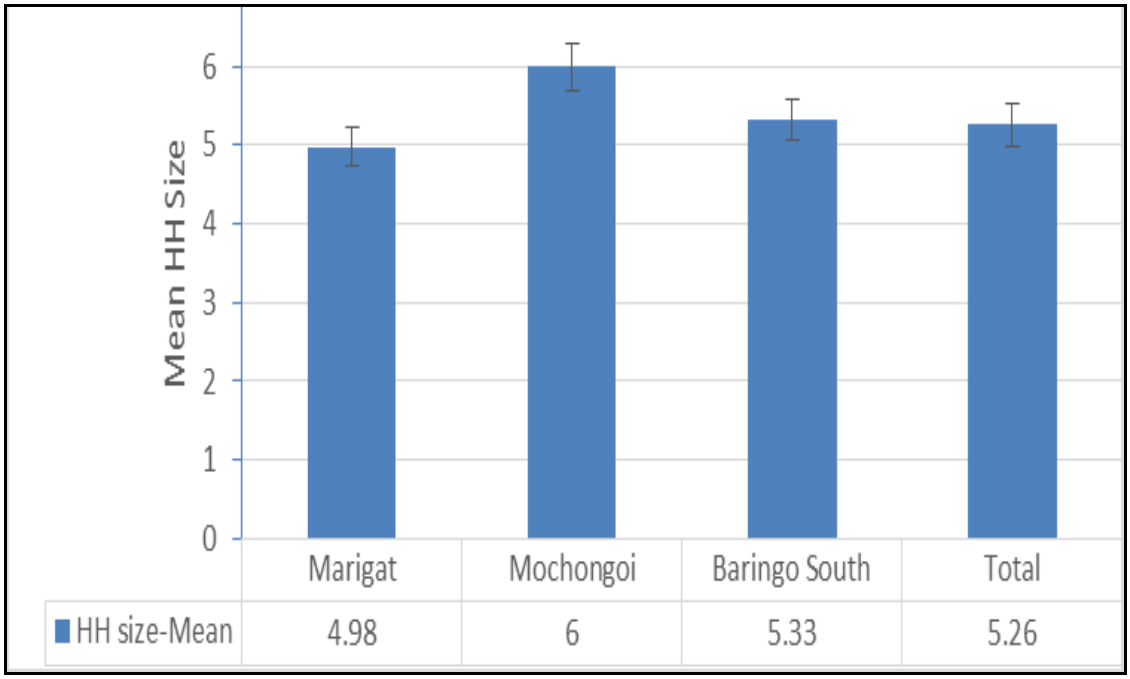

Figure 4.6: Mean household size

Household size affects workforce or labour availability at the household level. Households that were high adopters had at least six members while low adopters had slightly less. Agro-forestry has been reported to be labour intensive, meaning that families with less labour cannot afford to take up the technology. Household size was measured as a continuous variable, and as such, it is expected that household number will have a positive impact on the adoption of techniques and utilisation of *Prosopis juliflora*. The household size was

significant with a positive relation meaning that a unit increase in the household number will affect the utilisation and adoption of techniques for the utilisation of *Prosopis juliflora*. The Chi-square test analysis conducted for the levels of adoption of techniques and household size to test the relationships between the variables indicates that independent variable (household size) is statistically significant to the adoption and utilisation of techniques of *Prosopis juliflora*.

Table 4.9: The Household size of the respondents

	Average of HH Members
High degree (8 to 10 techniques adopted and used)	6.5
Moderate degree (4 to 7 techniques adopted and used)	5.7
Low degree (1 to 3 techniques adopted and used)	4.4
Test statistics	

Source: Survey data (2017)

4.4 Socio-economic benefits of *Prosopis juliflora*

Majority of the respondents (96.1%) are aware that the plant is beneficial while only a few 3.9% are not aware of the benefits of *Prosopis Juliflora*. The socio-economic survey identified the following uses of *Prosopis juliflora* in the study of the area. The study established that the most essential uses of *Prosopis juliflora* were as follows according to the frequency of use: charcoal (24.8%), shade (16.8%), fencing materials (12.6%), fuelwood (10.4%), and animal fodder (9.3%) among other uses (see Appendix 3, Results 7).

The *Prosopis juliflora* used for charcoal production (82 %) was the most frequently mentioned by the respondents and as shade for livestock and people was mentioned second (56%). The branches of *P. juliflora* were widely used as fencing posts (42%). The plant is also used as a source of fuelwood (34%), and fodder (31%) was also mentioned as the uses of *Prosopis juliflora* in the study sites. Figure 13 below, outline the benefits as indicated by the respondents during the survey.

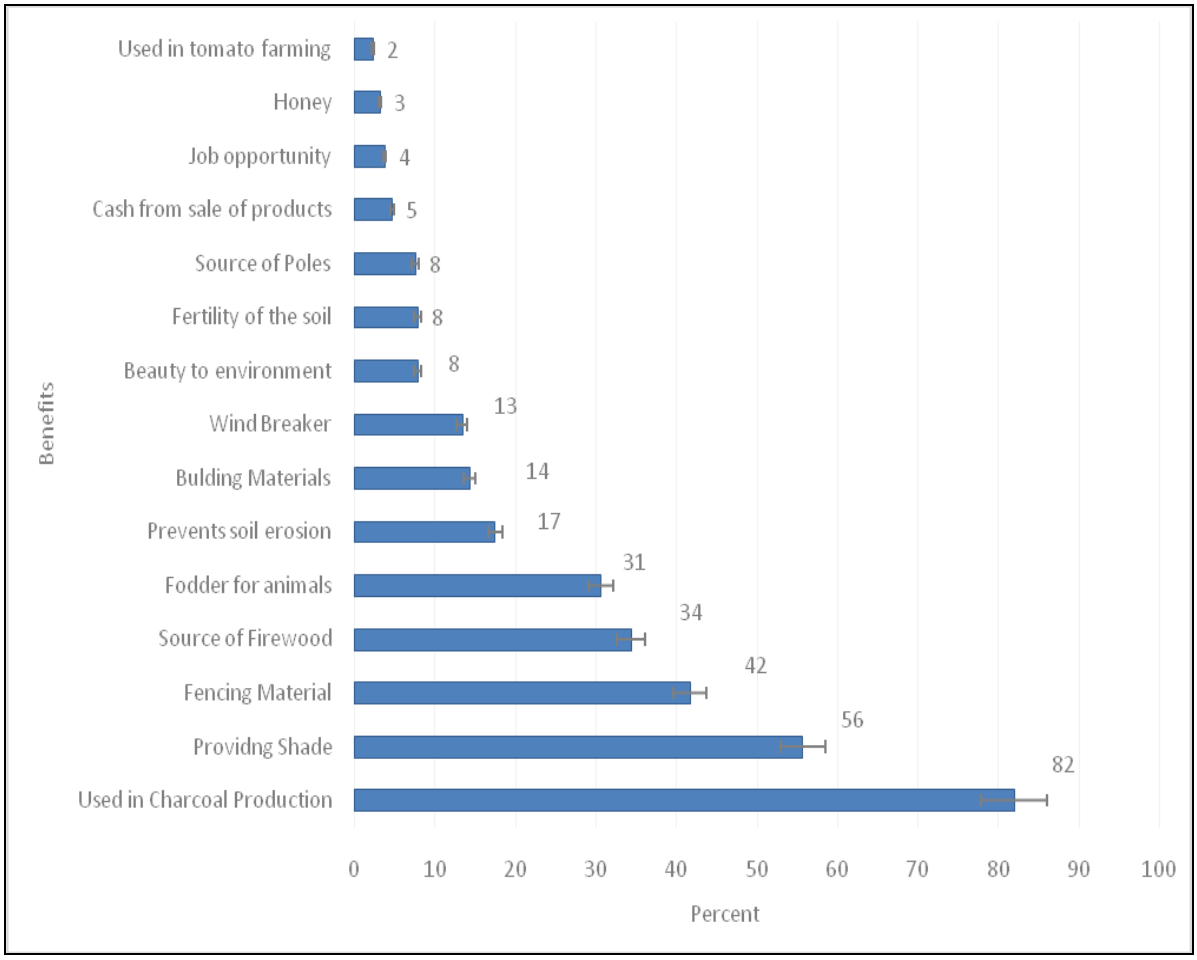

Figure 4.7: Benefits of utilization of *Prosopis juliflora*

4.5.2 Rate of utilization of *Prosopis juliflora*

The ecological benefits were measured as environmental health of the household farm, as indicated by the extent of regenerated pastures and desirable plant species.

The respondents indicated that the ecological benefit of *Prosopis juliflora* in the study area reducing soil erosion (n=60, 17%) and decreasing wind speed (n=46, 13%) as reported by the respondents as ecological benefits of the plant.

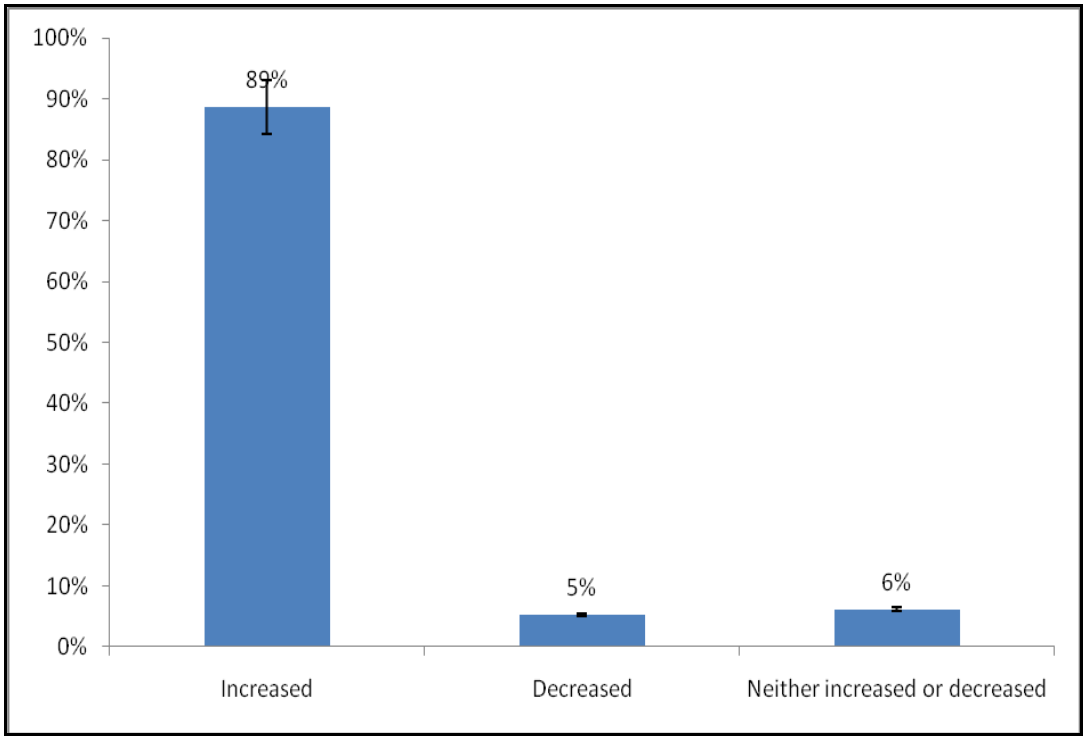

Figure 4.8: Rate of utilization of *Prosopis juliflora*

4.5.3 Economic benefits of *Prosopis juliflora*

Table 11 provides economic estimates of the benefits that individuals derive for each stated use in the study areas. Individuals generated average benefits of KES 9,945 from charcoal, KES 4,282 monthly from the use of fodder/pods as livestock, construction and fencing pole KES 4,946, honey KES 8,419, fuelwood KES 569, and ropes KES 441. By far, the most important product was charcoal with KES 9,945, among other benefits. Fencing materials, source of timber, poles and fodder and honey harvesting were the most important, generating more income on average from the value of *P. juliflora* products per household.

Table 4.10: Income of *Prosopis juliflora* per household per month

Economic use	Unit of measurement	Count	Mean income KES/Month	Sum income/Month	Min	Max	Stdev
Charcoal	Bags	337	9,945	3,282,000	200	180,000	21,037
Firewood	Backload	332	569	167,840	20	15,000	1,434
Fodder	Bags	213	4,282	766,390	100	50,000	7,797
Honey	Litres	222	8,419	1,902,750	200	400,000	28,762
Medicine	Kgs	9	619	38,350	100	8,000	1,232
Poles	Number	312	4,946	1,454,030	20	50,000	7,631
Ropes	Metres	131	441	31,285	5	5,000	817
Timber	Feet	171	8,161	1,379,170	20	75,000	12,609

Source: Survey data (2017)

The most important socio-economic impact of *Prosopis juliflora* is associated with its replacement of pasture lands and native trees of browsing value, which are the sole sources of feed for the livestock of pastoral communities. The negative features of *Prosopis. juliflora* are not limited only to its replacement of pastures and farmlands. Human and animal health has been harmed by the trees too. This is through piercing by thorns. The wound is not easy to heal, even using conventional medicine. Local communities in the study area noted a range of negative consequences arising from invasive *Prosopis juliflora.* These included effects on livestock health, deaths of cattle, goats and *Prosopis juliflora* thorns causing wounds, dense thickets reducing access to water points and roads.

4.5 Socio-economic and demographic modelling

The socio-economic and demographic characteristics that influence the adoption and utilisation of *Prosopis juliflora* are the age of the household head, education level, family size and gender of the household head. The output shows the results of fitting a multiple linear regression model to describe the relationship between adoption and six independent variables. The equation of the fitted model is

Adoption of *Prosopis juliflora* intervention techniques = 58.6063 - 0.15567*Age household head + 1.91806*HH members - 1.88052*labour total - 1.01967*Size of land+ 0.1439*Gender

Table 4.11: Multiple linear regression model

Parameter/variable	Beta (β)	Standard Error	T Statistic	P-Value
Constant	58.6063	7.26179	8.0705	0.0000
Age household head	-0.14155	0.0687149	-2.05997	0.0405
Amount in KES	-0.00003	0.000020085	-1.70357	0.0898
Education	-0.207295	0.166554	-1.24461	0.553
HH members	1.91806	0.723773	2.65008	0.0086
Labour	-1.88052	0.85688	-2.19461	0.0292
Size of land	-1.01967	0.264071	-3.86136	0.0001
Gender	0.143932	0.0683384	2.10616	0.0363

Source: Survey data (2017)

Table 4.121: Analysis of variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	6514.18	6	1085.7	8.43	0.0000
Residual	28836.0	224	128.732		
Total (Corr.)	**35350.2**	**230**			

Source: Survey data (2017)

Since the P-value in the ANOVA table is less than 0.05, there is a statistically significant relationship between the variables at the 95.0% confidence level. The R-Squared statistic indicates that the model, as fitted, explains 18.4276% of the variability in adoption. The adjusted R-squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 16.2426%. The standard error of the estimate shows the standard deviation of the residuals to be 11.346. This value can be used to construct prediction limits for new observations by selecting the Reports option from the text menu. The mean absolute error (MAE) of 9.34942 is the average value of the residuals. The Durbin-Watson (DW) statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in the data file. Since the P-value is less than 0.05, there is an indication of possible serial correlation at the 95.0% confidence level. In determining whether the model can be simplified, notice that the highest P-value on the independent variables is 0.2146, belonging to education. Since the P-value is greater or equal to 0.05, that term is not statistically significant at the 95.0% or higher confidence level.

CHAPTER FIVE

DISCUSSION

5.1 Socio-economic factors influencing the adoption and utilisation of *Prosopis juliflora*

Socio-economic factors are aspects that are related to social and economic conditions in the community. These include income, occupation, education, farm size and family size.

5.1.1 Income from *Prosopis juliflora*

Income from the sale of *Prosopis juliflora* products was found to be significant in the adoption of management techniques with a p-value of $P<0.001$. It is not surprising that income could play a major role in helping farmers decide to utilise *Prosopis* as a management strategy. Most of the respondents said that they benefit a lot from charcoal burning and that it has become one of the main revenue earners in the county. Since the area is semi-arid and sometimes the community losses their livestock due to drought and cattle rustling, income from the sale of charcoal plays a major role in cushioning the farmers from the losses. The study is in agreement with that done by Admasu (2008) who found out that households involved in charcoal production and sale obtained good income and had diversified their livelihood base to better cope with food insecurity. It also agrees with the study done by (Bekele and Girmay, 2013) who found out that *Prosopis* charcoal, grown and produced in Afar, was being distributed and sold in major Ethiopian cities including Addis Ababa and Mekelle. High income earners are also likely to hire people to carry out the *Prosopis juliflora* management practices in their farms, hence a higher adoption rate among high income earners

5.1.2 Education level and technology adoption

The result from the study indicates that a majority of those who adopted, 80%, *Prosopis* management techniques had primary education, while moderate adopters majorly had secondary education. Since the p-value was greater than 0.05(β= - 0.207, χ^2=14.579, df=9, F-value=0.699 p=0.553 >0.05), However, education of the household head was not significantly related to adoption in Baringo County due to labour and risk involved with its adoption and management. Marigat sub county is a semi-arid area, severe drought periods students drop out of school to go and fed for the animals this could have contributed to more respondents only reaching primary school level. These findings were in contrast with those of Okuthe *et al.* (2013), who indicated that there is a relationship between the level of

education and the practice of agroforestry. The results might have been different given that *Prosopis* is an invasive species, and the farmers would like to eradicate it. Most of the technologies for its management are labour intensive and might not depend on the level of education directly.

5.1.3 Farm size and adoption of technology

Land in semi-arid and arid areas is mainly communal land. The study found out that majority of the respondents (98.2 %) owned a piece of farming land despite them not having title deeds. Most of the 48.4%, had between 0.1-3 acres. Land ownership plays a key role in sustainable development. The p-value was found to be less than 0.05((χ^2=43.82, p=0.001<0.05), indicating that land size is significant in the adoption of *Prosopis juliflora* management technologies. This implies that farmers with the small land area have to manage *Prosopis* invasiveness to improve the productivity of their farms. They practised pruning, charcoal burning and harvesting of poles and posts. They were also continually removing regrowth's and planting other crops while those with large farms left the land for grazing encouraging infestation and spread of the *Prosopis juliflora*. These findings are in agreement with those done by Styger and Fernandes (2006), Nyamweya (2017)on the adoption of improved farm practices where they all stated that land size had a significant positive relationship with adoption of the technology. However, this study contradicted with Pisanelli *et al*. (2008), who found little influence on farm size with management technology adoption.

5.2 Demographic factors influencing the adoption and utilisation of *Prosopis juliflora*

5.2.1 Age and technology adoption

Age was found to be significant in the adoption and utilisation of *Prosopis juliflora* (p = 0.04 < 0.5). The mean age of high adopters was 36 while that of moderate adopters was 39. At this age, younger people tend to score higher on technology familiarity and are also likely to take it up faster than older people. They are able to actively participate in the utilisation of *Prosopis juliflora,* thus controlling its spread. As people age, they experience decreases in movement control, speed, coordination, sensation and perception (Rogers et al., 2013). These results are consistent with previous studies that have shown physical and cognitive capabilities to be positive predictors of usage of technologies (Gell *et al*, 2013) *Prosopis juliflora* has thick thorns that some people consider poisonous, making it relatively difficult to harvest and utilise. These findings are also in agreement with Amos (2007) who found out that new technologies are adopted faster and better by the young farmers and (Sezgin and

Kaka., 2011) who states that the age of the farmer had a positive influence on the adoption of artificial insemination.

5.2.2 The effect of Household size on technology adoption

The results indicate that majority of the respondents in the region have between 4-6 members in their household. The chi-square test analysis conducted to test the relationship between the variables showed that independent variable (household size) is statistically significant to the adoption of *Prosopis juliflora*, (for the levels of adoption of techniques (χ^2=41.217, df=24, p = 0.016 < 0.05). The high adopters had a mean of 7 members, while the low degree adopters had an average of 4 members. This implies that large households have sufficient labour to undertake management of *Prosopis juliflora* technologies most of which are labour demanding. For example charcoal burning and continues removal of *Prosopis juliflora* regrowth's to free the land for other activities (agriculture). This is in terdem with Madalco and Tefera (2016), who revealed a positive correlation between household size and agroforestry adoption in Ethiopia (r^2 =0.501). Bzungu *et al*. (2012) also found a positive correlation between agroforestry and household size r^2=0.5039 when he analysed the socioeconomic factors that influence the adoption of improved agricultural technologies in the Sahelian zone of Borno state, Nigeria. This also concurs with Ayuya *et al.* (2012), who stated that an increase in the household size by one member increased the likelihood of choosing agroforestry technologies by 5.57%. Given that *Prosopis julifora* is found on lands used for farming activities, its utilisation may be remotely classified as an Agroforestry benefit.

5.2.3 Gender and technology adoption

Gender issues are important globally due to the potential of marginalisation of certain groups, especially in terms of access and use of natural resources. It is also true that men and women interact and use natural resources in ways that may be very different. Table 13 revealed that there were more male adopters than female adopters at all levels; the high female adopters were 8.93% while the high male adopters were 91.07%. This suggests that men involve themselves more with the management of *Prosopis juliflora*, unlike their female counterparts, which could be attributed to the labour intense and risk involved in the management of *Prosopis juliflora.* It can also be attributed to cultural roles that dictate women roles in the community. These results were in line with findings by Kabwe (2010) stated that men were more likely to try improved technologies than their female counterparts. Literature has also stated that gender roles in the African setup are well defined according to Marenya and Barret

(2007). The fact that men adopted more than women is also as a result of the land ownership structure and access within the African setup. Men are more likely to own land, which is inherited from their fathers.

5.3 *Prosopis juliflora* control innovations adopted and the extent of utilisation

From the findings of the study, 36.7% of the respondents were low degree adopters of utilisation control technologies, while only 11% were high adopters. This is despite the fact that 99% of the respondents indicated that they were aware *Prosopis juliflora* grows freely in their area. Most of the households that practised pruning, charcoal burning and harvesting of poles and posts were those with small land sizes. This households were also continually removing regrowth's and planting other crops while those with large farms left the land for grazing encouraging infestation and spread of the *Prosopis juliflora*. These results are in agreement with those done by Shackleton (2015) who indicated that practices relating to *Prosopis julifora* differed between stakeholders and were linked to the social context of the stakeholder group. The results are also in tandem with those of Pratt *et al,* 2017 who indicated that invasive alien species threaten smallholder production. From the study, it was also noted that members of the community lost 29,027.78 KShs (about 290US dollar) per annum due to deaths of goats. They indicated that the animals lose their ability to feed after some time leading to the deterioration of health and eventually death. This could have contributed to the low adoption of utilisation as a control technique. The observation was similar to a report from Agar region in Ethiopia, where pastoralists were also experiencing the same effects of *Prosopis juliflora* invasion (Admasu**,** 2008).

5.3 Socio-economic impacts of *Prosopis juliflora*

Prosopis juliflora has multiple uses as a tree that can benefit the people if well harnessed. From the study, 91.1% of the respondents were aware that the plant is beneficial, while only 3.9% were not aware of its benefits. 24.8% of the people used the tree for charcoal production12.6% used it as fencing material, 10.4% used it as fuelwood, while only 9.3% used it for fodder. Table 11 indicates that they get a mean income of 9,945 KSH/month from charcoal and 8,419KSH from Honey. This shows that most of the household heads utilizes more of these two products than any other *Prosopis juliflora*. This is in line with Choge *et al*. 2012, who had shown that utilising *Prosopis juliflora* for charcoal production was economically viable indicated. It is also supported by Bekele and Girmay 2013 who also showed that *Prosopis juliflora* charcoal grown in Afar was being sold in major Ethiopian

cities. Wakie *et al.*,2016 suggested that making charcoal form it was profitable. From observation and inquiries made from the respondents, some of them were not only using *Prosopis juliflora*, but they were also using the indigenous tree (Acacia) for charcoal production which they claimed to earn more in the market. This has contributed to the deterioration of the species diversity in the area. There is a need to inform the communities that charcoal burning is only encouraged for management of *Prosopis juliflora* and that there is a need to preserve the indigenous tree species. Apart from the benefits, the community also complained that they are still losing animals due to *Prosopis juliflora*. However, this study has shown that if the communities could adopt the technologies, *Prosopis juliflora* would be of great benefit to the communities.

CHAPTER SIX

SUMMARY,CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

An examination of factors influencing adoption and control of *Prosopis juliflora* revealed that they are influenced by different factors at different levels of significance.

1. Farm size (P=0.001<0.05), income from the product of (P=0.006<0.05) and gender (P=0.001<0.05) has been found to be more crucial in adoption and control of *Prosopis juliflora* in Marigat sub County. Other factors which were also found to be influential but to certain stages were age (P=0.006) and family size (P=0.008<0.05).Education (P=0.553) does not influence adoption of *Prosopis juliflora* control and utilisation.
2. Adoption and utilization of *Prosopis juliflora* control measures is low 36.50 %(those who have adopted and are using 1 to 3 techniques). The moderate adopters are at 33.23% and high adopters of the control techniques are 21,36%
3. The study established that among the *Prosopis juliflora* control technologies advocated for in the study area charcoaling (82%)was being practiced more than any other

6.2 Conclusions

I. The results illustrated there are factors that influence adoption and control of *Prosopis juliflora* and, also that adoption was low (those who have adopted and are using 1 to 3 techniques)in the study area. This illustrates that it is not enough that a technology that addresses farmer needs has been developed but it also has to be adopted by a significant percentage of farmers in order to have impact.

II. Socioeconomic factors influence people's adoption and utilization of *Prosopis julifora* management and control in Arid and semi- Arid lands except education. Farmers with small land sizes adopted the technologies' more than those with large land sizes. They were continually removing regrowth's and planting other crops while those with large farms left the land for grazing encouraging infestation and spread of the *Prosopis juliflora*.

III. There was a positive significance correlation between demographic factors and adoption of *Prosopis juliflora* management and control technique. There are division

of labour in the community control *Prosopis juliflora* is done by different people along its value chain.

IV. Management by utilisation still remains the best method of controlling *Prosopis juliflora* in Marigat, though keeping the tree as a shade species may complicate matters. This is because the shade tree will continue to harbour seeds that encourage regrowth's of *Prosopis juliflora.*

6.3 Recommendations

1. It has been noted that different socioeconomic factors influence the use of *Prosopis juliflora* and hence its control and management. There is a need to clearly map out those that are positive contributors and promote them vigorously. Different extension approaches may be called and even changes in the way the community operates. Development of value chains that can positively utilise the species should be highly encouraged. This calls for the participation of all stakeholders.
2. The degree of adoption of the utilization of *Prosopis juliflora* is influenced by a multitude of factors. There is a need to have support structures that will encourage the adoption of technologies. If for example, markets for charcoal exist beyond the immediate area, these markets should be pursued within the national charcoal rules. Formation of the group for production and marketing could be one of the solutions. Financing of activities that promote adoption may also be considered as an option.
3. Demographic factors were also noted to affect the adoption and utilisation of *Prosopis juliflora* among households. Although there is nothing much we can do about family size, if a good economic model is developed for the area, migrant workers can come in to fill the labour gap. This will be a win-win situation for the residents and the newcomers.

6.4 Suggestions for future research

It is recommended that more research need to be carried particularly on the use of the species by the residents and better policy options developed to promote those uses that lag behind. Charcoal ranked first as a use, and this is linked to money obtained its sale. Shade ranked second for both man and animal. The retention of trees on land for shade may present a problem in control of the spread of seeds. Thus if the shade is an essential factor, then more resources and ideas should be directed towards finding alternatives for shade to limit this germplasm source.

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APPENDIX

APPENDIX 1: BENEFICIAL AND HARMFUL TRAITS OF *PROSOPIS JULIFLORA*

	BENEFICIAL TRAITS	HARMFUL TRAITS
1	Fodder for small stock	Invasive and fast-spreading; colonisation
2	Use for internal (household) fencing/livestock handling structure (pens), etc	Forms impenetrable thickets and choke other plants
3	Few harmful effects if right (superior) germplasm is propagated	Cause bare land, prone to erosion
4	Few harmful effects if proper management is applied	Lowers the groundwater table; survives better where moisture is excessive
5	Tolerates drought, grazing, heavy soils, sandy, saline soils, weeds, etc	Sugary pods cause tooth problems to goats (and kills them through indigestion)
6	Fast-growing; coppicing power	Cattle die after feeding on leaves over a certain period
7	Good for fuelwood (high heat, burns slowly and evenly)	Pollen cause allergy, asthma and lung inflammation to humans
8	Ideal for bee pasturage (nectar for good white honey). Vigorous and continuous flowering	Clogs irrigation channels (due to invasiveness)
9	Wood suitable for parquet floors, furniture, turnery items, fence posts, fuel, timber	Not adequately studied, e.g. the two varieties
10	Toasted seeds added to coffee used with human food	Powerful regeneration, out-compete other plants and eliminating them
11	Bark rich in tanning, good roofing	Displace farmers and animals
12	The gum forms adhesive mucilage, for an emulsifying agent	
13	Provides shade	
14	Provides soil stabilisation river banks, etc	
15	Fixes nitrogen	
16	Commercialized for household socioeconomic Improvement economic values	
17	Good for poles and posts	

APPENDIX 2: HOUSEHOLD SURVEY QUESTIONNAIRE

INTRODUCTION

Good morning/ afternoon. My name is: _____ (name of enumerator); Tel. No._____. I am conducting an assessment of socio-economic factors influencing the utilisation of *Prosopis juliflora* in Marigat, Baringo County, Kenya. The objective is to provide a better understanding of the socioeconomic and demographic factors that influence people's utilisation of *Prosopis juliflora*, given its many beneficial products and uses, and it is potential for household income generation and wellbeing. The information will be used for academic purposes and also help the government in its development planning. Please allow me to ask you a few questions. The information you provide will be treated with the most confidentiality it deserves. Thank you. (Provide any necessary additional information/ clarification/ answer where necessary)

SECTION A: BACKGROUND INFORMATION

Questionnaire No: ……; Date:……;

County: .....Constituency/Sub-County: .....;

Ward: .....; Location: .....

Sub-Location: .....; Village: .....;

Interview start time: .....

Interview end time: .....; Time took: .....

SECTION B: DEMOGRAPHIC INFORMATION

1. Name of Household head/Landowner: .....
2. Name of the respondent (if not Household head/Landowner):.....
3. **Relationship** with household head: [ ] (Self) [ ] (Wife) [ ] (Husband) [ ] (Son) [ ] (Daughter) [ ] (Other - specify): ..... (Tick where necessary)
4. **Age** of household head: _____ years.
5. **Gender** of household head: [ ] (Male) [ ] (Female)
6. What is your level of **education** of Household head: [ ] Primary; [ ] Secondary; [ ] Tertiary; [ ] Informal Education; [ ] Others (specify):
7. **Age** of the Respondents? …… (Age in years)

8. The main occupation of the household head: [ ] Salaried employment [ ] Work on the Farm [ ] Casual labour [ ] Self-employed business [ ] Forest products
   [ ] Other – specify:
9. What is your land **size** (in acres)? .....
10. Do you **own** this land? [ ] Yes [ ] No
11. Type of **ownership**: [ ] Individual [ ] Family [ ] Rental [ ] Other, specify.....

SECTION C: PROSOPIS JULIFLORAINTERVENTION

12. Have you had of *Prosopis juliflora*(Mathenge)? [ ] Yes [ ] No,
13. Does it grow in your area? [ ] Yes [ ] No
14. Where is this species found within your area?[ ]Own land [ ] community land [ ] government land
15. Do you think the plant is beneficial or not? [ ] Yes[ ] No. If yes what are the advantages of the crop?

    .....

    .....

16. The following table outline the benefits from *Prosopis juliflora (Mathenge)*, outline the economic benefits per household/month in Marigat

Economic use	Local Units	The quantity used per /month household	Amount in Ksh
Firewood	Backloads		
Poles	No		
Charcoal	Bags		
Fodder	Kg		
Medicine	Kg		
Honey	Litres		
Food	Kg		
Timber	No/ft		
Ropes	Meters		
Others specify ……	……..		

17. If No, in 15 above, please outline economic losses per household per year: Loss……..Kshs……..

SECTION D: ADOPTION OF INTERVENTIONS FOR UTILIZATION OF PROSOPIS JULIFLORA

18. Do you use Prosopis? [ ] Yes[ ] No, If Yes, what do you use it for? *(Rank uses in order of priority)*

    [ ] Fuelwood [ ] Charcoal [ ] Poles/posts [ ] Timber [ ] Fodder

    [ ]Honey [ ] Food [ ] Medicine [ ] Ropes [ ] Fencing [ ] Rehabilitation

    [ ] Ornamental [ ] Wood carvings [ ] Others (specify)…….....……

19. How often do you use *Prosopis juliflora (Mathenge)*? [ ] Always

    [ ] Once in a while [ ] Often [ ] Not at all

20. Have you ever earned from the sale of Prosopis product? [ ] Yes [ ] No. If yes, which product did you sell?.....How much?.....(Ksh)
21. How do you rate of adoption of the intervention techniques of *Prosopis juliflora* (Mathenge) within the community by households? (*This will be measured by the degree of use corresponding to the actual number adopted and used*):

[ ] High degree (8 to 10 techniques adopted and used)

[ ] Moderate degree (4 to 7techniques adopted and used)

[ ] Low degree (1 to 3 techniques adopted and used)

[ ] No utilization (0 techniques adopted and used)

22. Would you consider your life to have improved since you started using Prosopis?
    [ ] Yes [ ] No.

23. Are you in a member of any users group of *Prosopis juliflora (Mathenge)*?
    [ ] Yes [ ] No. If yes, which one?.....
24. Have you ever been trained in the use of *Prosopis*? [ ] Yes [ ] No. If yes, which one?..... Did the training improve your knowledge in the use of *Prosopis*? [ ] Yes [ ] No.
25. In your opinion, do you think the use of *Prosopis* has increased or decreased in the last five years?[ ] Increased [ ] Decreased [ ] Neither increased or Decreased
26. In your opinion, is the awareness' created by the government and other NGOs to control the spread of Prosopis effective? [ ] Effective [ ] Not effective. If "Not effective", why?.....
27. If effective which one of the following awareness methods do you think is more effective?[ ] Field days [ ] Trainings [ ] Shows [ ] workshops

APPENDIX 3: RESULTS

1. Adoption of techniques levels and mean amount from products

Adoption of intervention techniques of *Prosopis juliflora* by households	Female	Male	Row Total
High degree (8 to 10 techniques adopted and used)	11(14.47%)	65(85.53%)	76(22.78%)
Moderate degree (4 to 7 techniques adopted and used)	32(29.36%)	77 (70.64%)	109 (32.84%)
Low degree (1 to 3 techniques adopted and used)	36 (30.00%)	84(70.00%)	120 (35.50%)
No utilization (0 techniques adopted and used)	12 (40.00%)	18 (60.00%)	30 (8.88%)
Column Total	91 (27.16%)	244 (72.84%)	335(100.00%)

2. Correlations of Adoption and utilisation of innovations and Gender

		Gender of the household head	Often in the adoption of intervention techniques of *Prosopis juliflora* within the community by households
Gender of the household head	Pearson Correlation	1	-.139*
	Sig. (2-tailed)		.010
	N	335	335
Often in the adoption of intervention techniques of *Prosopis juliflora* within the community by households	Pearson Correlation	-.139*	1
	Sig. (2-tailed)	.010	
	N	335	335

*. Correlation is significant at the 0.05 level (2-tailed).

3. Cross-tabulation of adoption of techniques levels vs education levels

	The education level of the household head				
	Primary	Secondary	Tertiary	Informal education	Total
High degree (8 to 10 techniques adopted and used)	38	25	3	10	76
	50.0%	32.9%	3.9%	13.2%	22.7%
Moderate degree (4 to 7 techniques adopted and used)	44	42	7	14	107
	41.1%	39.3%	6.5%	13.1%	31.9%
Low degree (1 to 3 techniques adopted and used)	57	36	4	25	122
	46.7%	29.5%	3.3%	20.5%	36.4%
No utilization (0 techniques adopted and used)	16	3	2	9	30
	53.3%	10.0%	6.7%	30.0%	9.0%
Total	154	106	16	58	335
	46.1%	31.7%	4.8%	17.4%	100.0%

χ^2= 14.579, df=9, F-value=0.699, p-value= 0.553

4. Cross tabulation of adoption of techniques levels vs land sizes

Adoption of intervention techniques levels	0-3 Acres	4-6 Acres	7-10 Acres	10 Acres and above	Row Total
High degree (8 to 10 techniques adopted and used)	37	17	1	0	55
	14.62%	6.72%	0.40%	0.00%	21.74%
Moderate degree (4 to 7 techniques adopted and used)	61	28	6	7	102
	24.11%	11.07%	2.37%	2.77%	40.32%
Low degree (1 to 3 techniques adopted and used)	22	40	20	4	86
	8.70%	15.81%	7.91%	1.58%	33.99%
No utilization (0 techniques adopted and used)	4	4	2	0	10
	1.58%	1.58%	0.79%	0.00%	3.95%
	124	89	29	11	253
Column Total	49.01%	35.18%	11.46%	4.35%	100.00%

χ^2= 43.819891, DF=9, p-value=0.001

5. Adoption of techniques levels and mean amount from products

Adoption of intervention techniques of *Prosopis juliflora* within the community by households	Mean	N
High degree (8 to 10 techniques adopted and used)	11,898.68±1,624. 26	71
Moderate degree (4 to 7 techniques adopted and used)	14,117.27±3,051.30	111
Low degree (1 to 3 techniques adopted and used)	18,932.17±4,608.41	123
No utilization (0 techniques adopted and used)	2,800.00±827.63	30
Total	14,685.89±2011.74	335

χ^2=22.758; df =9, p-value=0.007,

6. Household size of labour

Location	Mean	N	Std. Deviation	Std. Error of Mean	F Value	P-value
Marigat	3.66	161	1.861	0.147	3.960	0.0292
Mochongoi	4.65	48	2.877	0.415		
Baringo South	4.03	131	2.219	0.194		
Total	3.94	340	2.186	0.119		

7. Uses of *Prosopis juliflora*

Uses of the Prosopis juliflora	**No of respondents**	**Per cent (%)**
Charcoal	281	24.8
Shade	191	16.8
Fencing materials	143	12.6
Firewood	118	10.4
Animals fodder	105	9.3
Prevents soil erosion	60	5.3
Building Materials(Poles, timber)	76	6.7
Windbreakers	46	4.1
Beauty to environment	27	2.4
The fertility of the soil	27	2.4
Sale of products	16	1.4
Job opportunity	13	1.1
Honey	11	1
Used in farming (Medicine)	8	0.7
Desertification(Rehabilitation)	4	0.4
Ropes	5	0.4
Good air freshening	3	0.3
Changes river course	1	0.1
Total	1135	100.0

Source: Research Data (2017)

APPENDIX 4: RESEARCH PERMIT

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Ref: KEFRI/52/03/16/01/Vol.II/(TY)

Date: 7th March 2019

TO WHOM IT MAY CONCERN

Dear Sir/Madam

RE: DATA COLLECTION

This is to inform you that Joyce Okumu of ID Number 298189 and P/No. KEFRI/5900 is currently a student in Egerton University undertaking Masters Degree in environmental science. She is currently undertaking a research project on **DETERMINATION OF FACTORS INFLUENCING ADOPTION AND CONTROL OF PROSOPIES JULIFLORA** in Marigat Baringo County, Kenya

Please assist her with the appropriate information to enable her complete her studies.

Thank you.

Joshua K. Cheboiwo (PhD)
DIRECTOR, KEFRI

APPENDIX 5: RESEARCH JOURNAL

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Factors Influencing Adoption of Management and Control Technologies for Prosopis juliflora in Marigat, Baringo County, Kenya

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Abstract
Prosopis juliflora is an invasive woody plant that was introduced to Marigat Sub County of Baringo County in 1970s and over the years its spread has altered the livelihoods of the pastoral communities who are the majority in most of the affected areas. This is because *Prosopis juliflora* invasion has reduced available dry season grazing fields, chocked river banks and interfered with access roads. To control its spread several management and control technologies were promoted in Marigat Sub-County in early 2004 that included clearing and planting pasture, charcoal production and killing of cut stumps with chemicals among others. However, the interventions have not yielded the desired results for the species has continued to spread into newer areas and intensifying their presence in already invaded areas. A study was initiated in 2017 to determine the factors influenced the local households to adopt the promoted management and control technologies in Marigat Sub-county one of the areas of original introduction and most affected by the infestations. The study was done through socio-ecological survey using questionnaires and checklist administered to 337 households. The factors considered were Socio-economic (education, land size income) and demographic (gender, age, household size). Data collected was then processed and analyzed using descriptive and inferential statistics of SPSS. The inferential tools used were chi-square analysis, regression and correlation analysis and Pearson Moment Correlation analysis. The results showed land size, incomes from Prosopis products, age and household size significantly influenced adoption of management and control technologies for Prosopis in the study area. The adoption rates association direction depended mostly on labour availability and incomes to hire extra labour for undertake the arduous job of Prosopis clearing and control of reinvasions. Level of education of the respondents had no significant effect on the adoption rates of the various control measures.
Keywords: Adoption, *Prosopis juliflora*, Management, Invasion and Household

1. INTRODUCTION

Prosopis species is listed among the world's most worst 100 species (Lowe *et al*., 2000 and Zeila, 2011). There are 44 *Prosopis* species as recorded but two of these species *Prosopis juliflora* and *Prosopis pallida* are exclusively tropical (Pasiecznik *et.al*, 2001). They are native to arid and semi- arid zones of America, Africa and Asia and are in the family Leguminosae (Fabaceas*)*. The *Prosopis juliflora* was first introduced in Africa through Senegal in 1822, South Africa in 1880 with subsequent introduction to Egypt in 1900. It is hardy and can tolerate harsh climatic conditions with rainfall as low as 150mm. Its introduction in Kenya was done in the early 1970s to address the increasing demands of forest resources and to improve vegetation cover (Esbenshade and Graige, 1980, Choge *et al*., 2007 and Sirma *et al*., 2008). The species adopted and naturalized very easily in Kenya, especially along the coastal region. *Prosopis juliflora* was introduced in Baringo County in the early 1980s with the good intentions of curbing soil erosion and to safeguard the existing indigenous vegetation from overexploitation by the local population as firewood (Lenachuru, 2003 and Choge, *et al*., 2007). It was part of the Kenya government policy of enhancing sustainable management of the drylands woodlands.

Aboud, *et al.* (2007) lists some seventeen (17) ecological and socioeconomic beneficial traits of *P.juliflora* based on surveys conducted in Marigat sub-county that include contribution towards rehabilitation of degraded areas and provision of timber, fuel, income and fodder to the local community (Mwangi and Swallow, 2005 and Sang, 2009). However, the rapid growth and spread of the species has reduced the available land for pasture in wetlands and many complaints from the local communities on its injurious attributes prompted the Government to declare the species a noxious weed in 2008 under the Noxious Weeds Act CAP 325. The declaration came to force in 2009 after its publication in the Kenya gazette notice no 184 (GoK, 2009). In the National Environmental Policy 2012, *Prosopis juliflora* is listed among the main contributor to loss of biodiversity and it is recommended to be controlled and contained to protect the environment in arid and semi -arid areas.

Despite the measures to control *Prosopis juliflora* in many parts of the drylands it has continued to spread invading more areas especially along rivers and roads (Richardson, 2001 and Shackleton *et al*., 2015). *Prosopis juliflora* like other invasive species are most of the time introduced intentionally or accidentally in an area before eliciting their negatively effect on the environment affecting social economic activities in the areas which they