IMPACTS OF *VACHELIA REFICIENS* AND *PROSOPIS JULIFLORA* ON SOCIO-ECONOMIC ACTIVITIES, ENVIRONMENT AND INTERVENTIONS IN SAMBURU EAST SUB -COUNTY, KENYA

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THESIS SUBMITTED TO THE SCHOOL OF NATURAL RESOURCES, TOURISM AND HOSPITALITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN ENVIRONMENTAL STUDIES (HUMAN ECOLOGY), MAASAI MARA UNIVERSITY

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DECLARATION

I hereby declare that this thesis is my original work and has not been presented or submitted in part or full for an award of a degree in Maasai Mara University or any other University. I further declare no conflict of interest in this work. In instances where explicit ideas and references have been made on contribution of others in the research, duly acknowledgments and citations have been made.

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DEDICATION

I dedicate this study to my family, environmental policy makers, planners and research scientists on invasive plants.

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ABSTRACT

Invasive species have been known to have enormous environmental and economic costs. In Samburu East Sub-County of Kenya, two common invasive species in the region *Vachelia reficiens* and *Prosopis juliflora* have been observed to have spread widely. The resident community and the government are concerned about the extent of the spread and establishment of the species in the area. To address these concerns, the study aimed at analyzing their impacts on socio-economic activities, on the environment and the spatial variations of impacts, and effectiveness of interventions in place. To obtain quantitative and qualitative data, sequential explanatory mixed-method study design was used. To achieve this, multistage clustered random sampling at each stage of the administrative units was used to obtain sampling design frame. Systematic sampling method was employed to get data from the household heads in each of the Ultimate Sampling Units. Structured research instruments were used to obtain data from 138 household heads, 10 Key Informants who were knowledgeable on the subject of the research, and 3 Focus Group Discussions comprising of mature persons of both gender knowledgeable on invasive species. Household heads questionnaire were pre-tested outside the study area. Kaiser-Meyer-Olkin index of 0.847 and Cronbach alpha reliability coefficient of 0.891 confirmed questionnaire validity and reliability respectively. Observation and photography employed to confirm species impacts and the physical environment. Data from household heads was analyzed using descriptive and inferential statistics while that of Key Informants and Focused Group Discussions was analyzed descriptively based on the dominant themes and narratives. To assess species impact magnitudes and efficacy of interventions measures, a perception count of a five-point Likert scale was used. The results show that impact of *Vachelia reficiens* were higher in magnitude than of *Prosopis juliflora* and the effective method of interventions was prescribed cutting. The results were statistically significant based on the chi square test analysis at $p < 0.05$. It was concluded that the two plant species have statistically significant negative impacts on the socio-economic activities; governance, livestock keeping, income and expenditure systems, local transport services and natural resource based conflicts, and environmental components; water availability, wildlife, land productivity, grasslands and natural regeneration of indiginous plants, and impacts differ over space. The variance between the impacts of the two plant species was statistically significant. The study recommends capacity building of communities and development of a management plan to guide on sustainable eradication of invasive plants and formulation of a policy. The policy to provide incentives, promote research, education, resource mobilization and allocations for the management of the invasive plants in the sub-county. Implementation of the recommendations will enhance environmental sustainability in the sub-county. It is expected that information from the study is useful to the Kenya government, Samburu County Government, development partners, resident community, rangeland actors, policy and decision makers in understanding, prioritizing and directing strategies, plans and actions on the management of the invasive species to safeguard environment and socio-economic activities for sustainable development in the sub-county.

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ACRONYMS AND ABBREVIATIONS

ACTED	Agency for Technical Cooperation and Development.
ASAL	Arid and Semi-Arid Land.
ASALs	Arid and Semi-Arid Lands.
A.S.L	Above Sea Level.
AU	African Union.
BETA	Bottom-up Economic Transformation Agenda.
CABI	Centre for Agriculture and Bioscience International.
CARITAS	Congregations Around Richmond Involved To Assure Shelter.
CBD	Convention on Biological Diversity.
CBOs	Community Based Organizations.
CEO	Chief Executive Officer.
CGS	County Government of Samburu.
CI	Confidence Interval.
CIDP	County Integrated Development Plan.
CITES	Convention on International Trade of Endangered Species.
CODES	Community Development Support.
COK	Constitution of Kenya.

COP_6	Conference of Parties (sixth).
DEAP	District Environment Action Plan.
EICAT	Environmental Impact Classification for Alien Taxa.
EU	European Union.
EUR	Euro (Currency)**.**
FAO	Food and Agriculture Organization.
FGs	Focus Groups.
FGD	Focus Group Discussion.
GESIP	Green Economy Strategy and Implementation Plan
GISP	Global Invasive Species Programme.
GOK	Government of Kenya.
GRIIS	Global Register of Introduced Invasive Species.
GTZ	German Agency for Technical Cooperation.
Ha	Hectares.
HH	House Hold.
IAP	Invasive Alien Plants.
IAS	Invasive Alien Species.
ICIPE	International Centre of Insect Physiology and Ecology.

IK	Indigenous Knowledge.
IPPC	International Plant Protection Convention.
ISSG	Invasive Species Specialist Group.
IUCN	International Union for Conservation of Nature.
JKUAT	Jomo Kenyatta University of Agriculture and Technology.
KALRO	Kenya Agriculture and Livestock Research Organization.
KEFRI	Kenya Forestry Research Institute.
KEPHI	Kenya Plant Health Inspectorate Service.
KERRA	Kenya Rural Roads Authority.
KFSSG	Kenya Food Security Steering Group.
KIs	Key Informants.
KII	Key Informant Interview.
KPHC	Kenya Population and Housing Census.
KRCS	Kenya Red Cross Society.
MDAs	Ministries, Departments and Agencies.
MEWNR	Ministry of Environment, Water and Natural Resources.
NACOSTI	National Commission for Science Technology and Innovations.
N.E.Br.	Nicholas Edward Brown (Taxonomist).

NEMA	National Environment Management Authority.
NFTP	Non-Forest Tree Product
NGOs	Non-Governmental Organizations.
PDF	Permanent Disc Format.
NRT	Northern Rangeland Trust.
RCMRD	Regional Centre for Mapping of Resources for Development.
SANBI	South African National Biodiversity Institute.
SDGs	Sustainable Development Goals
SDDP	Samburu District Development Programme.
SEICAT	Socio-Economic Impact Classification for Alien Taxa.
SERVIR	Eastern and Southern Africa (E & SA)-Satellite connectivity tool.
SPS	Sanitary and Phytosanitary.
SPSS	Statistical Packages for Social Sciences.
STCSG	Samburu Technical County Steering Group.
STDF	Standards and Trade Development Facility.
UN	United Nations.
UNCED	United Nation Conference on Environment and Development.
USAID	United States Agency for International Development.

VSF Veterinaires Sans Frontieres.

WFP World Food Programme.

OPERATIONAL DEFINITION OF TERMS

Biodiversity	Refers to variety of life on Earth at all its levels, from genes to ecosystems, and can encompass the evolutionary, ecological, and cultural processes that sustain life (Honor & Colauti, 2020).
Bio invasion	Species whose distribution within the last century extend their ranges from within a one region to cover large areas on several continents (Marbuah et al., 2014)).
Biome	Considerable size of a community of vegetation and wildlife acclimatizedin a destinct Climate e.g. forest biome (Nackley et al., 2017).
Concerns	Issues or problems residents of an area have and believe they affect their wellbeing (Crowley et al., 2017).
Environmental impacts	Multiple effects that change community composition, biotic interactions and other ecosystem processes (Wang et al., 2021).
Forage	Food for cattle, especially hay or straw (Eschen et al., 2021).
Homogenization of ecosystems	Means reduced species turnover across space (Wang et al., 2012).
Household head	Means the person acknowledged as taking the main responsibility for survival and nutritional wellbeing or care of the household members (Muellmann et al., 2021).
Indigenous plants	Plants that are native and not introduced to a specific

	geographical area of coverage (Kaigongi, 2020).
Invasive Alien plant	Refer to intentionally or non-intentionally introduced plant species in areas outside their native ranges and cause environmental degradation in areas they invade (Shiferaw & Demissew, 2022)
Invasive plants	Plants capable of establishing, naturalizing, and spreading regardless of the type of system in which it is present (Howard, 2019).
Invasive species	Subcategory of naturalized species that reproductive offsprings in unusually large numbers, with capabilities of spreading in over longer distances from a population and thus have the potential to spread to other areas over time and space. They can either be native or alien species (Shiferaw & Demissew, 2022).
Local extinction	The termination of a species (or other taxon) in a chosen geographical area of study, though it still exists elsewhere. It is also known as extirpation (Omollo et al., 2023).
Multi-purpose indigenous plants	Native plants used to provide a number of social, economic and ecological goods and services (Omollo et al., 2023).
Pasture	Plants or grass grown for the feeding especially of grazing animals in an area (Eschen et al., 2021).
Propagules	Vegetative structure when detached from a plant can give rise to a new plant e.g. a spore, bud, or a sucker (Johnston et al., 2009).

Propagules pressure	Described as a measure of the number of plants or animals released into an alien environment (Johnston et al., 2009).
Socio-economic impacts	Direct effects of a species on property values, agricultural productivity, public utility operations, native fisheries, tourism and outdoor recreation, as well as costs associated with efforts to control the impacts (Bacher et al., 2018).
Species Expansion	Establishment of invasive species within a new environment and their further spread through dispersal to cover large areas outside their native range (Colauti & Barnet, 2013).
Species richness	The number of different species represented in an ecological community, landscape or region (Nadio et al., 2020).
Taxa	Classification group of any hierarchy, such as a class, family or species (Hawkins et al., 2015).
Transformer species	Subclass of invasive plants which may not be alien as such, in an area that change the appearances, conditions and nature of an ecosystem over a significant area (Catford et al., 2012).
Weed	Plant taxon that has negative impacts or is perceived to be problematic by people (Nackley et al., 2017).

CHAPTER ONE

1.0 INTRODUCTION TO THE STUDY

1.1 Background of the Study

Invasive species have been described as either being indigenous or exotic and refer to species that are introduced with or without intentions into new areas and end up causing degradation of the environment they invade through their heavy colonization attributes. Invasive plant species differ with agricultural weeds as they have the ability to successfully establish and spread to new habitats without support from humans (Shiferaw & Demissew, 2022; Ng'weno et al., 2010; Burgiel & Muir, 2010; Colauti & Barrett, 2013). They invade areas of native vegetation, displacing many native species. They threaten and change the biodiversity, structure and functioning of several of the world's ecosystems (Mashhadi & Radosevich, 2004).

To safeguard biodiversity, Nations in the world have agreedto avert challenges posed by Invasive Alien Species (IAS). The invasion by invasive species is among the key environmental challenges of the 21st Century. The species cause erosion of global biodiversity and only rivalled by habitat degradation onloss of biodiversity (Noba et al., 2017). This led to the inclusion of Invasive Alien Plants (IAP) issues in the main sectorial themes of the Convention on Biological Diversity (CBD) on their management in aversion of their adverse impacts (Ten Kate, 2002).

Further, invasions by native plants have become a global concern and are adding to the challenges since the era preceding industrial revolution calling for sufficient attention. These invasions have claimed grasslands in affected countries and span Africa, Australia, Asia, North America and South America. In North America alone, the invasions now account for a fifth of the invasions. Their impacts on grasslands

negatively affects the ecological and economic role of grasslands in ecosystems of these countries (Nackley et al., 2017). Further to this, *Acacia drepanolobium* Harms ex Sjostedt-, is a native plant to North East Tropical Africa, East and Central African Regions. The spread and establishment of the plant in Borana rangelands of Southern Ethiopia, had threatened the livestock dependent pastoral economy, biodiversity and the livelihood certainty of most resident communities (Terefe et al., 2011).

Invasive species negatively affects the three pillars of sustainable development as they cause enormous biodiversity loss, economic and social impacts which have negative implications on environmental sustainability. They are key drivers of global ecological change. Invasions by IAS are irreversible and difficult to manage, therefore threatening biodiversity, economic development and human wellbeing. This constrains sustainable development by disrupting social and economic stability. Further, global measures to mitigate the arising negative impacts have been reported to be insufficient (Shackleton et al., 2014; Bufebo & Elias 2018; Howard, 2019)).

Due to environmental conditions caused by invasive species, responses to mitigate their impacts have been attempted-, Moles et al. (2008) developed prediction model to counter the invasions-, Bacher et al. (2018) and Hawkins et al. (2015), have developed quantification tools for impact assessment and classifications to determine impact magnitude of the species.

The invasions have been acknowledged as a man-made disaster which have evaded the attention of media and disaster managers (Gemeda, 2020; Obiri, 2011). However, increased attention of scientists, natural resource managers and policy makers on impacts of IAP on environment, economy and human health have been reported. The International Plant Protection Convention (IPPC) and the World Organization for

Animal Health (OIE) fostered a joint working relationships between relevant authorities in trade, agriculture and environment sector in the establishment and execution of statutory frameworks for the management of Invasive Aien Species (Luque et al., 2014; Lopian & Stephen, 2013). In Kenya, the legal frameworks are in place though poorly enforced and uncoordinated by a policy.

In Kenya, the distribution of *Vachelia reficiens* (Wawra & Peyr.) Kyal. & Boatwr, has been modelled and shown to reduce productive land under various land uses (Ouko et al., 2020). Regional Centre for Mapping of Resources for Development (RCMRD) developed an invasive plant software mapper and invasive plant mobile application to plot areas infested by *Vachelia reficiens.* These, tools are of value in the management of the species in Kenya (Nesoba, 2018; Unpublished). No mapper has been developed for *Prosopis juliflora* (Swartz D.C). Plate 1(At Lerata sub-location) and 2 (At River Seiya) shows photographs of the two plants and their impact on natural regeneration of indiginous plants (Author, 2023).

Plate 1: *Vachelia reficiens* Plant

Plate 2: *Prosopis juliflora* Plant

Invasive species poses risks to Kenya's vast ASALs and delay in management may make them uncontrollable. This was more so for *Prosopis juliflora* due to its invasive character as it coppices when cut, *Prosopis juliflora* was more aggressive in Marsabit County. It formed thorny impenetrable thickets in settlements and areas of high water table leading to serious conflicts with human Activities (Maundu et al., 2011). *Vachelia reficiens* is yet to receive attention though considered as an invasive species in some parts of Kenya (Ouko et al., 2020).

In Kenya, studies on invasive species and their impacts were restricted to areas of economic interests or public outcry as in the case of *Prosopis juliflora* in Baringo County (Choge et al., 2022; Obiri, 2011). In particular, ASALs have been understudied and social impacts have rarely been reported compared with economic impacts (Obiri, 2011). This is supported by few studies on rangelands such as; invasive plant species threatening Kenya's biodiversity by Ouko et al. (2020) and Ng'weno et al. (2010) on invasive species distorting food chains.

The Sub-County is an Arid and Semi-Arid Land, ASALs have been reported to be more vulnerable to and affected by invasive species (Obiri, 2011). *Vachelia reficiens* and *Prosopis juliflora* are woody plants which are difficult to eradicate once they mature and establish in an area, the land is communally owned, the surrounding Marsabit, Isiolo, Laikipia and Turkana Counties are negatively impacted by the two species in general and the invasions are expanding and spilling over to the Sub-County which is already experiencing internal spread and establishments of the two species among others (Samburu County Government County Integrated Development Plan, 2018; Kenya Food Security Steering Group, 2021).

The residents and government concerns on the spread and establishments of the two woody species across the Sub-County, prompted the study. This is expected to broaden understanding, information and knowledge base of the invasive plant species which may trigger their sustainable management to spur environmental sustainability.

In Kenya, negative impacts of these invasive plants can impend the sustainable implementation and attainment of a healthy environment pursuant to the Kenya Constitution (COK) 2010, Sustainable Development Goals (SDGs), Vision 2030, Green Economy Strategy Implementation Plan (GESIP) 2016-2030, 30% tree cover by 2032, and the Bottom-up Economic Transformation Agenda (BETA) in Kenya on green economy and environmental sustainability obligations to these policy documents. This is more so as the Phytosanitary and legal measures on invasive species in Kenya places more emphasis on prevention of entry to Kenya by invasive species and little measures on emerging and established invasive species.

Therefore, the study purposed to identify and determine the impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio and economic aspects, environment and evaluate current management measures in place, in Samburu East Sub-County, Kenya. The basic unit of data collection and analysis was the household.

1.2 Statement of the Problem

In recent years, there has been growing concern about the introduction and spread of invasive plant species in various parts of the world. Kenya as a signatory to the Convention on Biological Diversity (UN, 1992) and International Plant Protection Convention (IPPC, 1997), has recognized the importance of managing invasive species to safeguard biodiversity and livelihoods in the country. Since then, Kenya is obliged by these Multilateral Environmental Agreements to protect its territorial

boundaries from the incursion of invasive species. Due to this, it launched Institutions, enacted and operationalized Laws governing the management of invasive species. The pieces of legislation have emphasized more on prevention and are not coordinated by a comprehensive invasive plants policy which currently lacks in Kenya and are silent on invasive species which have escaped prevention and have established themselves in Kenya. This has curtailed holistic efforts to manage and control their spread. Native and non-native invasions have been informally reported to impact negatively on the Range lands of Samburu East Sub-County which supports livestock production, the economic mainstay of the local populace and are biodiversity hot spots of international importance (CGS CIDP, 2018; KFSSG, 2021). In particular, concerns on the negative impacts on land and biodiversity by *Vachelia reficiens,* a native plant, on Pastoralists in Samburu, Isiolo and Marsabit Counties in Kenya Exists (Nesoba, 2018; Unpublished). These impacts have not been identified and quantified in terms of magnitude in the sub-county to date. Additionally, information and research on diversity and impacts of invasive plants and management interventions is scanty in Kenya and lacking in Samburu East Sub-County which is mainly ASAL. Indeed, concerns on the establishment and spread of *Vachelia reficiens* and *Prosopis juliflora* across the Sub-County already exists and are worrying. Their impacts are yet to be identified, demystified and evaluated formally as this study purposes to do. These impacts if unabated may derail Kenya's attainment of 30% tree cover by 2032, Sustainable Development Goals (SDGs) and Vision 2030 among other envisioned economic and environmental plans and strategies.

1.3 Broad Objective

To assess impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio-economic activities of the residents, environment conditions and their interventions in Samburu East Sub-County, Kenya.

1.3.1 Specific objectives

The specific objectives of the study are to;

1. Determine the magnitude of impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio-economic activities of the residents of Samburu East Sub-County;

2. Assess the magnitude of impacts of *Vachelia reficiens* and *Prosopis juliflora* on the environment of Samburu East Sub-County;

3. Examine spatial variations of impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio-economic and environment aspects in Samburu East Sub-County and-,

4. Evaluate the effectiveness of on-going management interventions on *Vachelia reficiens* and *Prosopis juliflora* in Samburu East Sub-County.

1.4 Hypotheses

$H_{O\ 1}$: There are no significant socio-economic impacts of *Vachelia reficiens* and *Prosopis juliflora* on the residents of Samburu East Sub-County

$H_{O\ 2}$: There are no significant environmental Impacts of *Vachelia reficiens* and *Prosopis juliflora* on the environment in Samburu East Sub-County

$H_{O\ 3}$: There are no significant spatial variations of impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio-economic and environment aspects in Samburu East Sub-County

1.5 Justification of the Study

To prevent extinction of threatened species, Aichi target 9 of the Convention on Biological Diversity stipulates that by 2020 invasive alien species and pathways are identified and prioritized with a view of controlling or eradicating them and prevent their introductions and establishment (Convention on Biological Diversity, 2010; Hagerman & Pelai, 2016; Penchev, 2022). This Study provides information on the two species and their impacts on native systems for their management to improve and sustain conservation status of threatened species in the county and prevent their extinction. The information should be useful on status reporting and actions on the achievements of these targets of biodiversity conservation.

In comparison with the other two sub-counties in Samburu County i.e., north and central, Samburu East Sub-County is endowed with wildlife of global conservation significance and critically endangered species under the Convention on International Trade in Endangered Species (CITES), which are threatened by the invasive species. Additionally, it hosts community wildlife conservancies and supports nomadic pastoralism which is the economic mainstay of the populace. The information from this study may inform strategic approaches in terms of resource mobilization and allocation aimed at ensuring environmental sustainability for sustainable development in the sub-county.

Therefore, this study provides findings of a sequential explanatory research and complete analysis of the perceived socio-economic and environmental aftermath of *Vachelia reficiens* and *Prosopis juliflora* and their management in Samburu East Sub-County. The study comes with beneficial implications for decision and policy making in environmental management locally, nationally, regionally and globally. Information from this research on community's perceptions on the magnitude of the

species impacts, could therefore influence and guide policy formulation and implementation of policies related to the invasive plants in ASAL areas in general, in the county. The resultant policy may influence and spur sustainable management approaches and actions on the species in restoring and safeguarding environment and community general wellbeing therefore contributing greatly to the attainment of Bottom-up Economic Transformation Agenda (BETA), Vision 2030, Sustainable Development Goals (SDGs), Green Economy Strategy Implementation Plan 2016-2030 (GESIP), and a tree cover of 30% by 2032 in Kenya.

The findings of this study would add to existing knowledge, contribute to and enrich knowledge on the various invasive species and their impacts in the sub-county thus influencing decision making in prioritization of actions on invasive plant species posing significant impacts for proactive actions and trigger further research on key invasive species in the county. The information may further provide baseline information needed to formulate a policy on invasive species both at the county and national level.

Data from the study is crucial in the development and enrichment of a database on invasive species and related policies for use in education, extension and research packages and to build on knowledge on management of these species. In particular, the information will broaden databases and information on invasive species in ASAL areas in Kenya which have reportedly been understudied.

The findings of this study are expected to assist in the development of a management plan which is currently lacking, that will guide on the achievements of Sustainable Development Goals, food security in the Kenya 'Big Four-Agenda' among other policy documents. The data will assist with information on meeting the IPPC and

CBD objectives and obligations made by Kenya on habitats protection and conservation of biodiversity in abatement of adverse impacts caused by invasive species. The information will further influence the implementation of environmental sustainability aspects required for Kenyans to enjoy a clean and healthy environment pursuant to the Constitution of Kenya 2010. The outcome of environmental sustainability attained will further reduce exposure of the resident Community to Covid-19 pandemic. Therefore, the study will fill the information and research gaps on this environmental challenge posed by invasive species in the Sub-County and immensely contribute to the objectives of range lands restoration programmes in place and fulfillment of the Kenya Government commitments on economic and environmental recovery plans and strategies as mentioned above.

1.6 Significance of the Study

This study focused on the social, economic and environmental effects of *Vachelia reficiens* and *Prosopis juliflora* and explore viable and effective interventions in the Sub-County for use by Planners, biodiversity stakeholders, decision and policy makers in enhancement of environmental sustainability. The resultant environmental sustainability will spur environmental integrity and socio-economic advancement in the sub-county.

The data from the study is important as a baseline reference information to biodiversity stakeholders and Rangeland actors, who, while addressing matters of invasive plant species in Samburu East Sub-County could refer to. This may build on knowledge base for scholars and Rangeland managers on effective management of invasive plants in aversion of their negative impacts and development of an Inventory and database of priority list of invasive species in the county. The knowledge base is useful to scholars and researchers in advancement of research on invasive plant

species in the Sub-County. Scholars and researchers can use the data to identify further research potentials to spur research and close research gaps aimed at broadening the knowledge base of these species for their sustainable management by biodiversity stakeholders and natural resource management actors at both levels of government in Kenya.

Planners, decision and policy makers may use the data from the study to influence and justify formulation of a policy on invasive plants based on the impacts in the Sub-County. Information from of the study is useful on the thematic area of invasive species which is crucial to the County Environment Committee in the preparation and development of statutory Samburu policy documents by Samburu County Government such as County Environment Action Plan, County State of the Environment Report and County Integrated Development Plan.

The findings of the study may identify a the effective method of controlling or managing the invasive plants as identified by the study is useful to rangeland management actors and partners to suppress further spread through awareness creation, capacity building and restoration programmes for the invasive plant species to ensure sustainable development in the sub-county. The baseline data of the study can be used by natural resource managers to monitor the status, trend and management of the invasive species in relation to socio-economic and environmental systems and justify the need for a sustainable intervention to safeguard socio-economic and environmental systems in the sub-county. The baseline data is crucial for environmental managers and planners in development of a management plan that will guide sustainable management of the invasive plants in the Sub-County.

Rangeland actors may use the findings of the study as a basis to facilitate prioritization of actions, resource allocation and mobilization in the management of the invasive species in ensuring environmental sustainability. Drought disaster managers in the Kenya Food Security Steering Group (KFSSG) and National Drought Management Authority (NDMA) will use the findings of the study to integrate matters of invasive species management in drought mitigation matters as the species are believed to impact negatively on residents' economic mainstay and compound drought situation and climate change in the sub-county.

On Kenya's national and international obligations as contained in the CBD (2010) and IPPC (1997) on the identification and management of invasive species in safeguarding the environment and biodiversity, data from the study will be used by the Kenya Government to provide the status Reports of the invasive species and progress of their management as obliged and in monitoring progress made on their identification and management. Conservation authorities for instance International Union for Conservation of Nature (IUCN) can use the data to evaluate conservation status of major fauna and flora in regard to the impacts of invasive species on biodiversity and prompt further actions from the Union.

The information from the study will provide useful data for use by rangeland managers, scholars, environmental educators and researchers in developing extension packages aimed at creating awareness and capacity building of the communities and biodiversity stakeholders on sustainable management of invasive plant species in the Sub-County in attainment of Sustainable Development Goals and Kenya's policies on environment and green economy. On natural resource use conflicts, the security agencies in collaboration with natural resource managers will use the data from the study to map and prioritize conflicts hot spots occasioned by negative impacts of

invasive species for revival and strengthening of grazing plans and traditional governance systems for sustainable resolutions of arising conflicts.

1.7 Limitations of the Study

Expansive nature of the study target area occasional sparse nature of settlements and nomadic lifestyle of the local populace posed significant challenges to the study, Further, the costs of the study was enormous in terms of time and budgetary resources required in obtaining literature from libraries and institutions located far from the study area, and collection of raw data from a large geographical area.

To collect data from a large target population, 10% variability was employed to ensure the target population was reached through a multistage clustered random sampling technique instead of complete sampling frame. Further, to counter nomadic nature of the target population, data collection exercise was planned for the end of the rainy season in the area when the target population had relatively settled uniformly in their respective sub-locations and were available for the study. This was confirmed from planned inspections and adequate reconnaissance survey before data collection exrcise commenced.

Availability of and access to sufficient data for the study was challenging. This was countered by obtaining enough literature and experts opinions on the subject matter which was usefull in structuring of the research design and instruments before the study was embarked on. Further, the study employed sequential explanatory mixed-study design to capture sufficient quantitative and qualitative data from households, Key Informants and Focus Group Discussions.

On time and budgetary constrains on long distances travel to obtain published literature and information from libraries and institutions, online sources of literature particularly internet sources were relied upon heavily. This saved on time and finances.

Additionally, to save on time and budgets for the study, field enumerators recruitment and training on data collection was done onsite amongst the target population.

1.8 Scope of the Study

Data collection exercise was undertaken in the months of June and July 2022 during the onset of dry season when the vegetation was generally green and households' settlements were stable.

The study covered the sub-locations administrative units of Samburu East Sub-County. This was occasioned by community concerns on the spread and establishment of *Vachelia reficiens* and *Prosopis juliflora* across the sub-county compared with the two other sub-counties.

The study was limited to the assessment of the effects of the two plant species on five prioritized socio-economic activities and five environmental components, as identified and prioritized by Key Informants of this study as being key for impact assessment of the two species. The study aimed to evaluate the impacts of the plant species on these aspects, providing insight into their impacts on the environment, social and economic aspects of the resident pastoralists' community.

On socio-economic activities, the study focused on species impacts on; governance, livestock production, households' income and expenditure, local transport and natural resource use conflicts while on environmental components, impacts on; water

availability, wildlife, land productivity, grasslands and natural regeneration of indigenous plants. However, data for the study was limited to sub-locations which reported the existent of any of the two species. On control methods, the study narrowed on effectiveness of management interventions currently employed by the residents and stakeholders in control of the two species.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter presents theoretical framework of biological invasions of invasive species, studies done on the socio-economic and environmental impacts of invasive species, spatial variations of impacts and their management interventions globally as it narrows to impacts and interventions specific to Kenya and Samburu East Sub-County, and conceptual framework of the study.

2.1 Theoretical Framework of Biological Invasions of Invasive Species

Several explanations have been advanced to explicate invasion successes of species in particular ecosystems at the global scale (Gichua et al., 2013). Some of the hypotheses or models developed and advanced as to why species become invasive in the ecosystems around the world include.

2.1.1 Energy Release Hypothesis (ERH)

Introduced Plant species in an alien environment encounters a decrease of natural enemies or regulators (Gichua et al., 2013; Honor & Colauti, 2020). This results in an increase in their distribution and abundance due to lack of natural controls or regulators. They then utilize the strength of lack of natural enemies to grow, spread and increases in populations. However, existence of natural enemies of the invasive plants have not been confirmed by literature in East Africa (Gichua et al., 2013). The theory relates to *Prosopis juliflora* an introduced species in Kenya and in the sub-county. The study intends to establish whether the plants' natural enemies exist or not in the study area through direct observation, open-and-close ended questions to Respondents in an explanation to the spread of the two plant species in the sub-county.

2.1.2 Evolution of Increased Competitive Ability (EICA)

These are changes in plants allocating resources to growth rather than defense to improve their competitive ability. However, controversies exists in the hypothesis as performances of invasive species have been found to differ. This because some species have shown higher performance while others have not shown. Further, examples exists where some invasive populations showed a decline of their competitive ability. This hypothesis was not convincing in explaining the success of introduced species (Gichua et al., 2013).The study is unlikely to rely on this theory due to scientific involvements which are out of scope in this study.

2.1.3 Novel Phytochemistry

The hypothesis relies on invasive plants possessing novel biochemicals for their defense. This biochemicals are works as allelopathic agents of actions in new plant-soil microbial interactive activities. Lack of information and data in the East Africa region to validate the existence of this agents challenges this hypothesis (Gichua et al., 2013). The reported impacts of undergrowth suppression by the two species has been be explored through the study to examine whether it applies to the two species as perceived by the Respondents.

2.1.4 Appearance of More Vigorous Genotypes

This are genetic changes and impacts of considerable small populations, flow of genes and hybridization, natural selection and adaptation which makes species develop superior vigours thus becoming vibrant in the environment. Lack of published information on *Prosopis juliflora* diverse space gene pools as a result of increased introductions of the species disqualifies this hypothesis (Gichua et al., 2013). . The study has not borrowed from this theory as it requires scientific investigation to ascertain this fact.

2.1.5 Increased Resource Availability

This hypothesis suggests that availability of plants' resources for growth increases the invasions and has not been contested from disturbance regimes and is likely to apply to East Africa (Gichua et al., 2013). The study has employed open-and-closed-ended questions on sites mainly colonized by the two species to explore the possibility of the species colonizing specific sites on availability of soil moisture and nutrients in explanation of the relevance of the theory on species prevalence and spread.

2.1.6 The Role of Disturbance

On anthropogenic activities, intensity of disturbance qualifies to change a plant community vulnerability to invasions. Reduced competition, higher resource availability, and increased introduction of species may validate this theory (Gichua et al., 2013). The species are reported to colonize overgrazed areas and accelerate soil erosion. The study has attempted to link the role of disturbance and the spread of the species through closed -and-open ended questions in the sub-county.

2.2 Empirical Studies on Invasive Species

On invasive plants, Nackley et al. (2017) developed a checklist of characteristics exhibited by invasive plant species to guide in determining whether a plant is invasive or not. Table 2.1 illustrates the features displayed by invasive plants.

Table 2.1: Characteristics of Invasive Plants

S.No.	Traits exhibited by invasive plants
1	When a plant spreads widely as opposed to normal known distribution.
2	Reports of invasiveness in other parts of the country.
3	Climate changes influences their distribution.
4	The plant displaces or dominates or over tops other vegetation.
5	Plant becomes risky to the health human and animals.
6	The plant uniquely impacts negatively on grazing systems.
7	Form thickets which are difficult to move through thus impending movement..
8	Plant exhibits many vegetative reproduction modes, for instance vegetatively and by seeds.
9	The plant becomes a heavy seeder in the year.
10	Plant's Propagules dispersals are aided by mammals, insects, livestock, birds, or wildlife.

Source: (Nackley et al., 2017: Pg., 3)

There are 622 types of invasive plant species (357 tree and 265 shrub species) recorded in the world. They are heavy seeders, able to spread over several life cycles, displacing indigenous plants and colonizing Sites (Richardson & Rejmánek, 2011). In parts of East Africa rangelands, a variety of invasive woody plants have been known which calls for their sustainable management (Obiri, 2011).

However, in Kenya the reported number of major invasive plant species differ, for instance; Gichua et al. (2013), identified 8; Obiri (2011), documented 9; Kedera & Kuria (2005), reported 9. This shows lack of harmonized information on number of invasive plants. Surprisingly *Vachelia reficiens* (*Acacia reficiens*) though a native

plant, is not in the list yet concerns on its spread and extent of expansion have been informally reported in several counties in Kenya.

Table 2.2: Invasive Plants and Their Impacts in Kenya

No	Botanical Name	Sites Infested	Impacts
1	*Prosopis juliflora* Swartz D.C (Mesquite)	Kenya Africa ASAL mainly	Depletes pasture, Puncture tyres, displaces biodiversity, degrades agricultural land, Injurious to livestock, Blocks access routes
2	*Lantana camara* L. (Tick berry)	tropics	Displaces native plants
3	*Pistia stratiotes* L. (Nile Cabbage)	Worldwide Lake Victoria	Clogs water bodies and irrigation channels
4	*Thevetia Peruviana* (Pers.) K. Schum (Yellow oleander)	East Africa	Poisonous to humans and most animals
5	*Caesalpinia decapetala* Roth) Alston (Mauritius thorn)	Naturalized in East Africa	Chokes vegetation, Clogs water infrastructure
6	*Datura stramonium* L. (Jimson weed)	Africa	Reduction in crop yield
7	*Tecoma stans* L. (Yellow bells)	World wide	Weed like tendencies in riparian areas and road sides.
8	*Argemone mexicana* L. (Mexican poppy)	Tropical areas	Poisonous to livestock
9	*Opuntia exaltata* (A.Berger) D.R Hunt (Long spines cactus)	Dry areas	Hinders growth of grass and indigenous vegetation, Injures animals.
10	*Opuntia ficus indica* L. (Sweety prickly pear)	Rangelands	Chokes grass and indigenous vegetation, Injurious to animals.
11	*Opuntia vulgaris* Mill. (Drooping prickly pear)	Marginal areas	Suppresses grass and indigenous vegetation, Injury to animals, Worst weed
12	*Eichhornia crassipes* Mart. (Water hyacinth)	Lakes, Rivers	Clogs waterways, encourages the spread of water-borne diseases and increases evapo-transpiration

Source: (Obiri, 2011: Pg. 421; Gichua et al., 2013: Pg., 46; Kedera & Kuria, 2005: Pg., 2)

The identified and documented major invasive plant species in Kenya are shown in Table 2.2. The plants were intentionally introduced to Kenya from tropical America, Asia and Britain for various uses; economic, ornamental, and conservation-to fight

desertification and soil erosion. They instead turned invasive and catastrophic. Their seed dispersal are aided by man, livestock, wildlife, wind, water, birds and they propagate by seeds and vegetative structures. Other documented species include; *Prosopis pallida* L. (Mesquite), *Psidium guajava* L. (Guava), *Acacia farnesia* L. (Sweet acacia), *Acacia mearnsi* D. Wild (Black wattle), *Acacia polyacantha* Wild. (White thorn), *Salvinia molesta* DS Mitchell (Water fern), *Allium vineale* L. (Wild garlic), *Tagetes minuta* L. (Mexican marigold), Ipomoea species (Morning glory) and Eucalyptus species (Obiri, 2011; Nackley et al., 2017; Kedera & Kuria, 2005).

Additionally, Witt and Van Wilgen (2018; Pg., 220) identified *Senna didymobotrya* (Fresen.) and *Calotropis procera* (Aiton) R.Br. as invasive plants in Kenya. This brings the total numbare of reported invasive plant species in Kenya to 24.

Species invasion dominantly drives ecological change leading to negative changes in ecosystem structure and functions, economic and social systems in the world. The species directly affects nature and caused 60% of species extinctions. These impacts are exercabated by the difficulty to control or reverse the invasions. Additionally, Climate change, habitat fragmentation and global trade noted to increase their abundance and severity of the impacts by facilitating movement of seeds and vegetative structures (Howard, 2019; Sintayehu et al., 2020).

Climate change aids the introduction, establishment and spread of invasive species to unifested higher altitudes. This disrupts native ecosystems thus increasing environmental disturbances that creates further opportunities for invasive species to spread and establish (Shiferaw et al., 2018).

Economically, the impacts of invasive species are massive and disastrous yet little policy commitments exists to reverse their impacts in Kenya (Choge et al., 2022).

Globally the economic cost of invasive species has been 1.288 trillion (US$) over the past five decades and on the upward trend (Zenni et al., 2021). Biological invasions contributed to water deficit and loss of biodiversity in South Africa. Impacts of climate change and drought then became severe (Van Wilgen et al., 2022). Generally negative socio-economic and environmental impacts of invasive plant species outweighs their economic benefits (Howard, 2019). There socio-economic costs are yet to be established in the study area and in Kenya.

To meet Vision 2050 on biodiversity values, substantial efforts are required to counter their increased impacts calling for considerable commitments on efforts, resources and cooperation among stakeholders. This was more so as the species have capacities to out-compete or prey on native species, therefore increasing habitats vulnerability to biological invasions (Essl et al., 2020).

Impacts of Invasive species in Sub Saharan Africa have been described to include; livelihoods losses, food scarcity, and biodiversity loss. These threatens the economic stability and advancement in the affected areas. Cosequences of invasive on the environment include; decline in species richness and abundance, a decrease in availability and quality of ecosystems goods and services including water, and wildfires. Frequent floodings and pollution incidenes as a result of excessive use of chemicals to control invasions as additional environmental effects (Witt & Van Wilgen, 2018). However, impacts of the two species under focus have not been confirmed in the sub-county thus the focus of the study.

In South Africa *Terminalia sericea* (Burch. Ex D.C), and *Vachelia karoo* (Hayne) by encroaching to biomes, have claimed tens of millions of hectares thus affecting their structure, composition and functions. Invasions by native woody species such as

Juniperus virgiana L. (Juniper), *Prosopis glandulosa* Torr. (Mesquite) and *Larrea tridentata* (D.C) Cov. (Creosote bush), have claimed close to a half a million hectarage of grasslands in the USA. Further, *Quercus garryana* (Dougl.), and *Pseudotsuga menziesii* (Mirb.) in the Northwesterly of USA have converted prairies to woodlands thus changing their structure, composition and functions. The altered competitive dominance of trees and grass negatively affects the Earth-atmosphere ecological interactions of savannas iconic biodiversity, wildlife populations and livestock grazers. This has changed the composition of savannas constraining their global significance as they occupy a fifth of the earth's land surface (Nackley et al., 2017).

Vachelia reficiens (Acacia reficiens) has been described as a shrub or tree growing to a height of 3-4 metres high.It has a flattened top and has reddish-brown branches. It occurs naturally in a number African countries such as; Ethiopia, Somalia, Kenya, Namibia, Sudan, Uganda, and Angola. The species is an aggressive invader in disturbed or undisturbed areas (Ouko et al., 2020). The species has been renamed *Vachelia reficiens* following the decision of the International Code of Botanical Nomenclature and ratified at XVIII IBC, Melbourne in 2011 (Kaingongi, 2020).

Further, *Prosopis juliflora* (Swartz D.C) is one of the worst woody invasive plant in the world and has been included in the IUCN red list of invasive species. The plant is evergreen and has a fast growth and belongs to the legume family. It is indigenous to Mexico, South America and the Caribbean. It grows to a height of 12 metres and has spines. It forms impenetrable thickets, and at maturity, the stem diameter is 1.2 metres. Recently the plant has turned out to be a problematic weed in pastoral and agro-pastoral communities of Ethiopia, Kenya and generally in the Eastern Part of Africa (Abdulahi et al., 2017*).* The plant threatens biodiversity and overtakes other

land uses thus reducing their ecosystem services (Shiferaw & Demissew 2022). *Prosopis juliflora* is a serious invader and has caused great ecological and economic damage in Ethiopia (Sintayehu et al., 2020).

Prosopis juliflora is an alien plant species intentionally introduced to Kenya in 1980's to solve degradation of Arid and Semi-Arid Lands (ASALs) by stopping the spread of desertification in these areas (Gruber et al., 2021). It was objectively introduced from South America in the 1970s to rehabilitate ASALs of Kenya on account of its resilience and fast growth attributes. It further provides a number of benefits such as-,fodder, socio-economic goods and environmental Services including carbon sequestration, stabilization of soils by its extensive rooting systems and fixation of atmospheric nitrogen as it belongs to the legume family (Mwangi & Swallow, 2008).

2.3 Socio-Economic Impacts of Invasive Plant Species

The total estimated cost of Invasive Alien Species to agriculture in Africa is 65.58 Billion (USD) on management costs, losses in crop yields losses and reductions in income derived from livestock which constitutes the majority of the costs (Gruber et al., 2021). In Europe, total economic costs of IAS was 140.2 Billion (US$) by 2020 (Haubrock et al., 2021). In South Africa, IAP have costed South Africa approximately 6.5 billion Rand an equivalent of 450 million (US$) annualy. These are in terms of lost water, grazing potentials and biodiversity losses. These costs are projected to increase in absence of management measures (Van Wilgen & De Lange, 2011).

In Africa, Mali as a country, experiences incidences of malaria as *Prosopis juliflora* encourages increase of female anopheles mosquitoes population. The plant, damages animal graze areas and out compete native plants. This had impacted directly on, human health, income and expenditure of resident communities (Muller et al., 2017).

Vachelia reficiens and *Prosopis juliflora* are among other four invasive plants which have decimated pasture in Samburu East Sub-County. They have compromised food security and constrained pastoral-based economy of Samburu pastoral community hampering their livelihood security and resilience (Kenya Food Security Steering Group, 2021).

Invasive plant species in Kenya have threatened native wildlife and vegetation putting at risk human health and economies dependent on healthy native systems of the environment (Ouko et al., 2020). *Prosopis juliflora* invasion had reduced the capacity of pastoralists to keep large herds of livestock in affected areas. Future expansion scenarios will affects people's livelihoods and key sectors of the economy such as tourism (Maundu et al., 2011). The impact of *Prosopis juliflora* among pastoralists' communities had led to frequent lawsuits among communities in Baringo County against the government. The plant thrives in areas of high-water table such as ravines, floodplains and swamps causing conflicts with human activities (Obiri, 2011).

Prosopis juliflora is among the ten invasive plant species that affect dry lands and comes with disaster effects such as; death of livestock due to poisoning, injuring and destruction of livestock foliage. The plant suppresses the growth of indiginous plants therefore increasing loss of biodiversity and livestock foliage. Thickets it forms are breeding ground for mosquitoes and other insects which carry human and livestock ailments. The plant had triggered major socio-economic impacts leading to increased poverty among resident communities in areas it has infested in East Africa rangelands (Obiri, 2011).

Vachelia reficiens spreads and establishes rapidly in grasslands and degraded landscapes. It suppresses and displaces plants including grass by producing chemicals

which chokes other plants nearby or underneath. The loss of the vegetation cover as a result of the invasion aggravates degradation of land catalyzing the invasion by invasive species (Nesoba, 2018; Unpublished)). The impacts the plant has on livestock production in terms productivity and mobility due to decreased land potentials to support herbivory has not been given attention as focused by the study.

Vachelia reficiens invasion of rangelands in Northern Kenya has encroached into productive rangeland and grasslands. These has diminished their capacities to support livestock production. The plant hinders the growth of grass palatable to livestock. This had caused the disruption of wet-dry season grazing patterns leading to high livestock mobility in search of pasture elsewhere. This had deprived residents' reliable access and benefits to many of the livestock products (Kimiti et al., 2020).

Key socio-economic impacts of invasive plant species documented around the world are summarized in Table 2.3.

Table 1.3: Key Socio-Economic Impacts of Invasive Plant Species

	Socio-Economic Impacts
1.	Disorderly governance systems-institutions, laws and rules, systems, observance to human rights
2.	Changes in economic activities e.g., livestock keeping to charcoal burning or trade, and dependence to external support
3.	Decrease in agricultural productivity-Livestock production in terms of livestock numbers, quality of products and carrying capacity
4.	Increased cost of living-reliability of income, changes in expenditure patterns.
5.	Degraded Cultural services/Sacred sites-availability and integrity of the sites.
6.	Reduced beekeeping potentials or access to NFTP –availability and quality of resins, gums, honey, and fodder.
7.	Declining tourism potentials-tourist numbers, dependability, circuits.
8.	Deterioration of livestock health-body conditions, health, quality and availability of pasture.
9.	Negative impacts to human health- injury and disease transmission, food availability.
10.	Obstructs local transport-access to food and water sources,-Access-, education services, health care services, and other services.
11.	Heighten conflicts-Human-wildlife, Resource use conflicts (internal, external).
12.	Displacement-internal migrations, emigration of people or animals.

Source: (Nackley et al., 2017; Bufebo et al., 2018; Eschen et al., 2021)**.**

2.4 Environmental Impacts of Invasive Plant Species

Egypt as a country has recorded; 10 plant species and 5 animal species of major concerns as invasive species which have had great negative impacts to ecosystems (Amer, 2021). Listed species found in Kenya include; *Biden pilosa* L., *Ipomoea carnea (*Jacq.), *Prosopis juliflora Swartz D.C* and *Solanum elaeagnifolium* Cav. but little information is available on these species in Kenya except for the *Prosopis juliflora.*

Ipomoea carnea has potentials to become a problematic invasive plants in Egypt particularly along water bodies. The plant is a shrub and originated from South America. Its colonization ability is attributed to its fast growth, spread and adaptability to aquatic to dry habitats and had colonized canals, drains, roadsides and field edges. Further, limited research on invasions by weeds worsens the situation as data on IAP is scanty and bias on Nile Delta due to economic interests (Hegazy et al., 2008). This is critical to Kenya as many invasive species have been reported and little attention has been given to manage them.

In Afar Region of Ethiopia *Prosopis juliflora* uptake of water was estimated to be 3.1 -3.3 billion m^3 per year impacting negatively on water availability and provision of other ecosystem services, therefore threatening rural livelihoods. Its invasion threatened indigenous palatable grass and multipurpose trees due to its high-water uptake potentials thus exacerbating effects of climate change (Shiferaw et al., 2021).

Invasive plants introduced to East Africa have escaped cultivation and invaded protected areas, forest and mountain ecosystems reducing biodiversity leading to serious changes to the structure, composition and functions of these ecosystems. This has claimed livelihoods of millions of people dependent on these ecosystems for goods and Services (Ng'weno et al., 2010). The study gave little attention to the variation of environmental and socio-economic impacts among these ecosystems.

Africa's arid and semi-arid rangelands, have experienced an increase in invasive species responsible for reductions of indigenous vegetation cover (Ouko et al., 2020). Invasive plants in Africa have claimed pasture land and persisted in cultivated lands as weeds. All invasive plant species have been found to limit the diversity of indigenous Species. Their spread and establishment have greatly contributed to the

reduction in grass productivity and species diversity. This further has resulted on a decrease of forage availability and quality. Due to this, they are detrimental to wildlife dependent on savanna (Kimiti et al., 2020). However, the study had not quantified the impacts nor expounded on the type of species affected by the invasive species.

In the entire dry forests and rangelands of East Africa, a disaster is in the waiting as a result of the loss of biodiversity occasioned by invasive species. The disaster, has not been adequately reported despite of the decline and loss of the biodiversity. The invasion had at long last led to societal disasters like emigrations from infested areas. This calls for efforts to free invasive species from the environment to foster environmental sustainability and socio-economic development (Obiri, 2011). Due to this, the study is justified on account of the presence of invasive species in the study area as concerns on frequent migrations have also been informally linked to the invasion caused byinvasive species.

Though Kenya is endowed with diverse geographical regions and habitat diversity, it is enormously impacted negatively by climate change.The resultant habitat diversity supports diverse varieties of plants and animals though threatened by invasive species (Ouko et al., 2020). Invasive plants lower grass production by degrading the capacity of grasslands to support grass thus decreasing food availability to grazers. Further, invasive plants are a second threat to wildlife after poaching as they destroy ecosystems and harm wildlife. In particular, parthenium weed has been reported to distort food chain as it taints the flesh and milk of grazers. In addition to this, Lantana species causes mouth blisters among grazers yet it is unpalatable to livestock and wildlife (Ng'weno et al., 2010). The study had not quantified the decline of grass production and the invasive species responsible for the decline.

Invasive plants vibrantly competes with indigenous species for their food in terms of moisture, nutrients and light and space leading to the alteration of the strucuture and functions in terms of nutrient cycling of ecosystems in terms of nutrient cycling. This has changed the interactions of the living and non-living organisms, therefore, distorting ecosystem services hence causing environmental damage. Invasive species have threatened biodiversity in Mali by suppressing growth of indigenous and endemic plants. They have overtaken ecosystems leading to extinction of species such as *Eichhornia crassipes* Mart. (Muller et al., 2017).

Invasion of northern Kenya's rangelands and grasslands by *Vachelia reficiens* has undermined the conservation of endangered wildlife species by lowering their capacities to support grass and forage available for wildlife (Kimiti et al., 2020).The study was restricted to the impacts of the plant on endangered wildlife other than wildlife in general probably due to conservation interests. The study further excluded *Prosopis juliflora*, an invader plant of similar impacts to wildlife and grasslands elsewhere. This study has broadened the impact of *Vachelia reficiens* to a wide range of environmental components for a holistic assessment of its many other environmental impacts and included *Prosopis juliflora* in the assessment.

Prosopis juliflora encroaches on human-built infrastructure such as paths, dwellings, irrigation schemes, crop farms and pasture land. This has a significant impact on biological biodiversity and rural livelihoods. This was confirmed in three sites assessed which showed a significant plants diversity outside *Prosopis juliflora* thicket than within it. Further, it was evident that, in areas where *Prosopis juliflora* was well established, it was beyond the community's ability to control its expansion (Maundu et al., (2011). *Prosopis juliflora* aggravates drought and soil erosion by loosening the soil structure through its deep roots making it unable to sustain water. The plant has

lush growth, and forms thickets which encourages the breeding of mosquitoes that transmit malaria (Obiri, 2011). This is an ecological disaster and that no attempts have been made to assess the impacts of *Prosopis juliflora* and *Vachelia reficiens* in the sub-county.

Diverse communities of plants and animals generally exhibits higher ecosystem functioning than less diverse ones. Loss of biodiversity will reduce ecosystem productivity and functioning as little biomass is produced. Impacts of *Prosopis juliflora* are far reaching when its canopy cover is 40%. The tree cover directly causes losses in indigenous species richness (Linders et al., 2019).

In areas where *Prosopis juliflora* had established its population, it encroaches on native vegetation, making no other plant to grow (Mwangi & Swallow, 2005). *Prosopis juliflora* vibrantly colonizez areas occupied by indigenous vegetation and had negatively impacted on landscapes, human and livestock health. It colonizes and blocks installed infrastructures and wildlife habitats. Critical wetlands in Kenya such as River Tana, Lorian swamp, and Lengurruahanga have reportedly been invaded by *Prosopis juliflora*. Attempts to eradicate the plant in affected regions and wetlands have been described as near impossible thus spelling an ecogical disaster (MEWNR, 2013).

Modeled prediction of distribution of *Vachelia reficiens* and Opuntia species have shown their population to likely increase under future climatic patterns. Current extents are expected to triple by the year 2070. Opuntia specie has spread very fast and became a naturalized invasives in ASAL areas of northern Kenya. Its invasion has constrained rural livelihoods and ecosystem functioning. Their future rates of expansion is projected to reduce suitable habitats within conservancies over different

climatic regimes. Their seeds are dispersed by animals mainly elepphants and water thus explaining the common distribution of their population mainly along the streams and banks of rivers where water table is high (Ouko et al., 2020).

In Samburu County, *Vachelia reficiens* has been acknowledged to suppress natural regeneration of vegetation including grass believed by Samburu pastoralist community as of high value to livestock production and livelihoods Further, areas encroached by *Vachelia reficiens* have been reported to generally lack herbaceous understorey and bare grounds are prevalent (Kimiti et al., 2020). *Vachelia reficiens* is a species that is indigenous to South Africa and has colonized former grasslands in parts of northern Kenya causing widespread destructions to pastoralists. The species is spreading fast suppressing other plants as it emits a biochemical agent that chokes other species. This had aggravated land degradation in the ASALs rangelands. The degradation had greatly interfered with ecosystems by changing their structure and composition in northern Kenya (Nesoba, 2018; Unpublished).

Sites cleared of *Vachelia reficiens* (*Acacia reficiens*) and reseeded with *Cenchrus ciliaris* found increases of more than 25% in overall ground cover, 34% in perennial grass cover, and 60% in standing herbaceous biomass. This implies the negative impacts of the species in colonized sites on plant species richness (Kimiti et al., 2020). However, the study did not put efforts in identifying the specific plant species and the experiment targeted two conservancies as opposed to the entire sub-county which is the focus of this study. Further, the study excluded *Prosopis juliflora* which has been considered a vibrant invader of the northern rangelands.

In addition to this, Kimiti et al. (2020), found the spread of *Vachelia reficiens* in the ecosystem was of great concern. The species has been found to reduce both habitat for

endangered wildlife species like the Grevy's zebra as well as available forage for pastoral communities. The study restricted the impacts of *Vachelia reficiens* to one endangered species rather than wildlife in general and other endangered wildlife.

Key environmental impacts of invasive plant species documented around the world are summarized in Table 2.4.

Table 2.4: Key Environmental Impacts of Invasive Plant Species

	Environmental Impacts
1.	Grow densely in an area hence form unpassable thickets thus hindering movement or transportation.
2.	Depletes water sources inducing water scarcity.
3.	Cause displacement of rangeland biodiversity.
4.	Aesthetics degradation-reduced beauty of sceneries.
5.	Reduces rangelands productivity-loss of graze areas/land degradation.
6.	Hinders seedling establishment-natural regeneration in rangeland.
7.	Disrupts natural flow of ecosystem services and goods-food, fodder, microclimate.
8.	Interferes with plant diversity hence loss of biodiversity.
9.	Reduced habitat quality through degradation.
10.	Wildlife impacts-decreased availability of forage and grass.
11.	Changes composition of faunal community through reduction in wildlife numbers as a result of, displacement and eventual dispersion.
12.	Degradation of ecosystems-reduced flow of ecosystem goods and services.

Source: (Nackley et al., 2017; Bufebo et al., 2018; Eschen et al., 2021)

2.5 Spatial Variation of Impact of Invasive Plant Species

Invasive Alien Plants have shown larger physiology and growth rate in tropical regions than in temperate regions (Van Kleunen et al., 2010). Invasive Alien Species (IAS) have a complex pattern of spread in time and space. Their spread extends

beyond geographical and jurisdictional boundaries, thus affecting multiple actors who have conflicting values, priorities and goals (Adoyo et al., 2022). In Afar Region of Ethiopia *Prosopis juliflora* invasion and water uptake was higher in dry lands compared with the flood plains (Shiferaw et al., 2021).

The spatial assessment of *Prosopis juliflora* invasion of riverine and non-riverine areas in Turkana County showed a decline in population of key forage species in heavily infested riverine areas compared with less infested non-riverine ecosystems thus threatening the socio-economic livelihoods of the local populace. Its invasive nature has decreased plant species richness and diversity in infested areas of the county (Nadio et al., 2020). No literature is available on the spatial impacts of *Vachelia reficiens* thus a further justification of this study. This further suggests that the plant is understudied and its impacts may be biting unnoticed.

2.6 Management Interventions of Invasive Plant Species

Management efforts to mitigate degradation in Kenya caused by invasive plants exists. This attempts have not been monitored, evaluated or reported to inform restoration and rehabilitation activities in order to replicate best practices to other areas including the study area (Kimiti et al., 2020).

To sustainably manage IAP, a well planned-all inclusive Programme at all levels suffices. The programme should adopt more than one control methods for synergistic benefits. Creation of awareness in areas infested and provision of capacity building services to establish strong technologies and research dissemination are mandatory. Language friendly networks for dissemination to the society are key to effect management. The networks, technologies and research findings need publicity coverage of both print and electronic media (Abdulahi et al., 2017). Current methods

in use in the Sub-County are yet to receive sufficient media coverage as to upscale dissemination of control methods for their adoption.

Negative impacts of invasive species has prompted the adoption of integrated management measures to mitigate their adverse impacts. However, this has faced a number of challenges as demonstrated by; Choge et al. (2022), on lack of adequate capacity to detect and implement management measures, and Gichua et al. (2013), on existent of limited policy environment in East Africa, Irreversibility of impacts and financial costs implications of invasive species. Lack of harmonized policies on invasive species in Kenya and the study area is believed to derail mitigation efforts on invasive plants.

Biological invasions are complex processes requiring coordination and spatially targeted management (Adoyo et al., 2022). To prevent introductions of invasive plants is a feasible and cost-effective option to halt the spread of invasive species. The choice of precise method of control depends on; growth forms of targeted invasive species, labour availability, intensity of invasion, topography of the area infested and capital required. Further, integrated management approaches provides sustainable management of these invasions (Weidlich et al., 2020). Methods of control also depend on economic status of a country, for instance-, economically welloff countries use chemical control, whereas developing countries use mainly non-chemical methods e.g. mowing by use of machines and prescribed fires. Integrated interventions is the most cost-effective approach to invasive species management. Prevention and integrated approaches taking the lead (Venette et al., 2021).

Best management practices on invasive species and dissemination of information serves the higher goal of preserving biodiversity on earth. Cost of human labour

dictates the use of physical labour and where it is costly, volunteer groups are recommended. Physical methods are effective when the population of invasive is small and infested area is smaller too and the species do not resprout after cutting. Residue treatment through composting and burning of uprooted or cut material prevent chances of them propagating (Weber, 2017).

Policy approach and political good will, early warning information systems, clear cutting and control attempts as well as increased public awareness, constitute local and national actions required to solve the problem of Alien Invasive Species (Gichua et al., 2013). Integrated programmes targeting the management of invasive plant species include; Community voluntary systems, Public-Private Partnerships entities and government-led public education schemes to capacity build communities as effective integrated approaches. These when combined are effective on invasive species management (Casey, 2021). Information on some of these programmes in Kenya is scanty as to inform management of invasive species.

Methods of controlling invasive differ from country to country. Use of chemicals and fire due to its environmental impacts have been banned in Ethiopia. Use of biological agents, physical cutting to induce natural regeneration and animal grazing in enclosures in rotations to increase organic matter in the soil and encourage natural regeneration of vegetation are environment friendly attempts of managing invasive plants (Shiferaw et al., 2018).

Kenya National Prosopis Strategy (NPS) was formulated in 2022 to curtail the spead of *Prosopis juliflora* and reduce its densities. Kenya National Strategy and Action Plan (2021) aims at sustainably managing the species using integrated methods such as; biological, chemical, mechanical, and utilization methods. The strategy targes on

removal of *Prosopis juliflora* trees and restoring these sites by promoting suitable agroforestry technologies and practices. The strategy outlines governance measures for timely prevention and detection of invasions to minimize impacts of *Prosopis juliflora*. The strategy states the need to promote the capacity and participation of the National and county governments in the management invasions (Choge et al., 2022). The strategy is bias as it only focuses on *Prosopis juliflora* and excludes other notable invasive plants in Kenya including native species which have been acknowledged as invasive plants.

Lack of coordinated strategy to manage *Prosopis juliflora* has increased its spread and establishment in ASAL environment. The high rate of spread has impended its utilization for fuelwood with damaging negative outcomes on ecosystem goods, services and livelihoods of pastoral communities and farmers (Choge et al., 2022).

Control by utilizing invasive species on various ways in combinations with use of biological agents, burning, prescribed chemicals, manual cutting, and mechanical control methods have been pointed out as effective methods to control and manage plants which have turned to be weeds in Ethiopia. Manual control is effective and economical if manual labour is available as it is cheap in the management of invasive plants at their earlier stages of growth and development. Debarking or girdling may also provide a solution only for eradicating invasive shrubs and treespecies that do not resprout after cutting (Abdulahi et al., 2017). This calls for early, effective and timely management of *Vachelia reficiens* and *Prosopis juliflora* as they have coppicing ability which makes them resprout after cutting.

Modern mechanical and chemical methods of controlling *Prosopis juliflora* have been unsustainable. Though controversial, Utilization of *Prosopis juliflora* for economic

benefits to residents is the best option to control the invasion of many invaded areas. By doing so, the spread of *Prosopis juliflora* can be controlled with a possibility of eradication (Tessema, 2012). Eradication and utilization practices of *Prosopis juliflora* in Ethiopia have targeted conversion of infested areas into irrigated agriculture, charcoal and flour production to feed livestock (Wakie et al., 2016).

Tree cutting with fire as a browse cobination, cutting and burning, stem burning, mechanical cutting and browsing, and cutting treatments immensely increased mortality of *Acacia drepanolobium*, *Senegalia melifera* and *Vachelia reficiens* in the rangelands of Ethiopia. Mortality was higher in *Vachelia reficiens* compared with the other two species. This showed that woody plant species exhibited higher mortality rates and were responsive to selective thinning and post management practices. Further, management measures after thinning were observed to sustain savanna ecology, if implemented progressively (Hare et al., 2020).

Manual clearing of *Vachelia reficiens* (*Acacia reficiens*) in the dry season combined with reseeding, before-and-after treatment of seed,soil and water conservation practices are potentially efficient and cost-effective solution to help reverse habitat degradation and losses (Kimiti et al., 2020). The study gave little attention to other methods of controlling the plant which could have been more effective or could be integrated with manual clearing to enhance the control of the plant.

In Samburu East Sub-County, Civil Society Organizations together with the resident community are cutting down the *Vachelia reficiens* trees manually. The cut materials are spread to protect the soils from erosion agents and area reseeded with suitable grass species. To sustain the intervention, deferred grazing systems are put in place to

safeguard natural regeneration (Nesoba, 2018; Unpublished). However, no effective or sustainable method of eradicating the species has been identified in the sub-county.

Coppicing ability of Prosopis species have hindered the success of mechanical and chemical eradication programmes in several countries. Thinning and pruning to reduce biomass and density of prosopis seedlings to promote undergrowth of indigenous species have been found to be a reliable method of control. Cutting of Prosopis creeping roots and old growth and bark-treating with herbicides further reduces its re-growth. During pod-bearing stage grazing on Prosopis infested areas to prevent seed dispersal is recommended. Burning during winter also control young Prosopis trees from flourishing. Integrated herbicide use with fire is an effective method in managing dead wood material (Hare et al., 2020; IIukor et al., 2016)).

Biological control methods have become popular in several countries as the most sustainable and reliable option of managing substantial infestations by invasive plants. Bio-control, checks on the population of the invasive plant by weakening its competitive ability thus suppressing its density and environmental impacts. This promotes resilience of the native population to recover (Venette et al., 2021).

Inter-specific hybridization of *Prosopis juliflora* with *Prosopis pallida* has challenged attempts at Bio-control. Seed-feeding beetles -*Neltumius arizonensis* Schaeffer, *Algarobius prosopis* J.L. Leconte and *Algarobius bottimeri* Kingsolver, introduced from North America, has been attempted in South Africa to control invasive plants. Eradication attempts of *Prosopis juliflora* have been proven difficult, as it requires adoption of sustainable management and control technologies (Kleinjan et al., 2021).

On biological control of Opuntia, the moth *Cactoblastis cactorum (*Berg.), has been found to control Opuntia *exaltata* as the insects, larva feeds on the plant. This can

support an integral programme which can help control *Opuntia exaltata* when combined with mechanical methods of trimming. Several Opuntia species are fed on by Cochineal species and found successful through trials in Laikipia County, Kenya. Bio-control agent, *Dactylopius opuntiae* (Cockerrel) 'stricta' biotype was released once in 2014 on experimental basis to feed on Opuntia and was able to control the plant compared to physical or chemical control in Laikipia County (Witt et al., 2020).

2.7 Literature Gaps

Most studies on invasive species have been restricted to developed countries with little attention in Africa and Kenya in particular. Paucity of literature on *Vachelia reficiens* as an invasive plant suggests that the plant is understudied despite of the concerns on its spread and establishment in Samburu East Sub-County. The study is expected to provide information on invasiveness of the plant and its socio-economic and environmental impacts in the Sub-County.

Information on quantified impacts of *Vachelia reficiens* and *Prosopis juliflora* is unavailable suggesting lack of its research in the county. Mapping of population distribution only done for *Vachelia reficiens*. Invasive plant species management Programmes and their outcomes have been poorly reported if existent, as little information is available on them. Research on sustainable methods to control particularly *Vachelia reficiens* is lacking.

No theories have been advanced to explain the successes of plant species invasions in the Sub-County. Total Economic Valuation of impacts of the invasive species in terms of monetary loss in Kenya has not been researched and reported. In Kenya spatio-temporal impacts of *Vachelia reficiens* and *Prosopis juliflora* has not been done to date.

Therefore, the study picked on some of this literature gaps to help in filling some of the gaps and advance knowledge on the invasive species in the sub-county.

2.8 Conceptual Flow Chart of Biological Invasions

Invasion series of mechanisms and dynamics of invasions, policy and management options to counter invasion from the point of entry to the point of damage creation are shown in Figure 2.1.

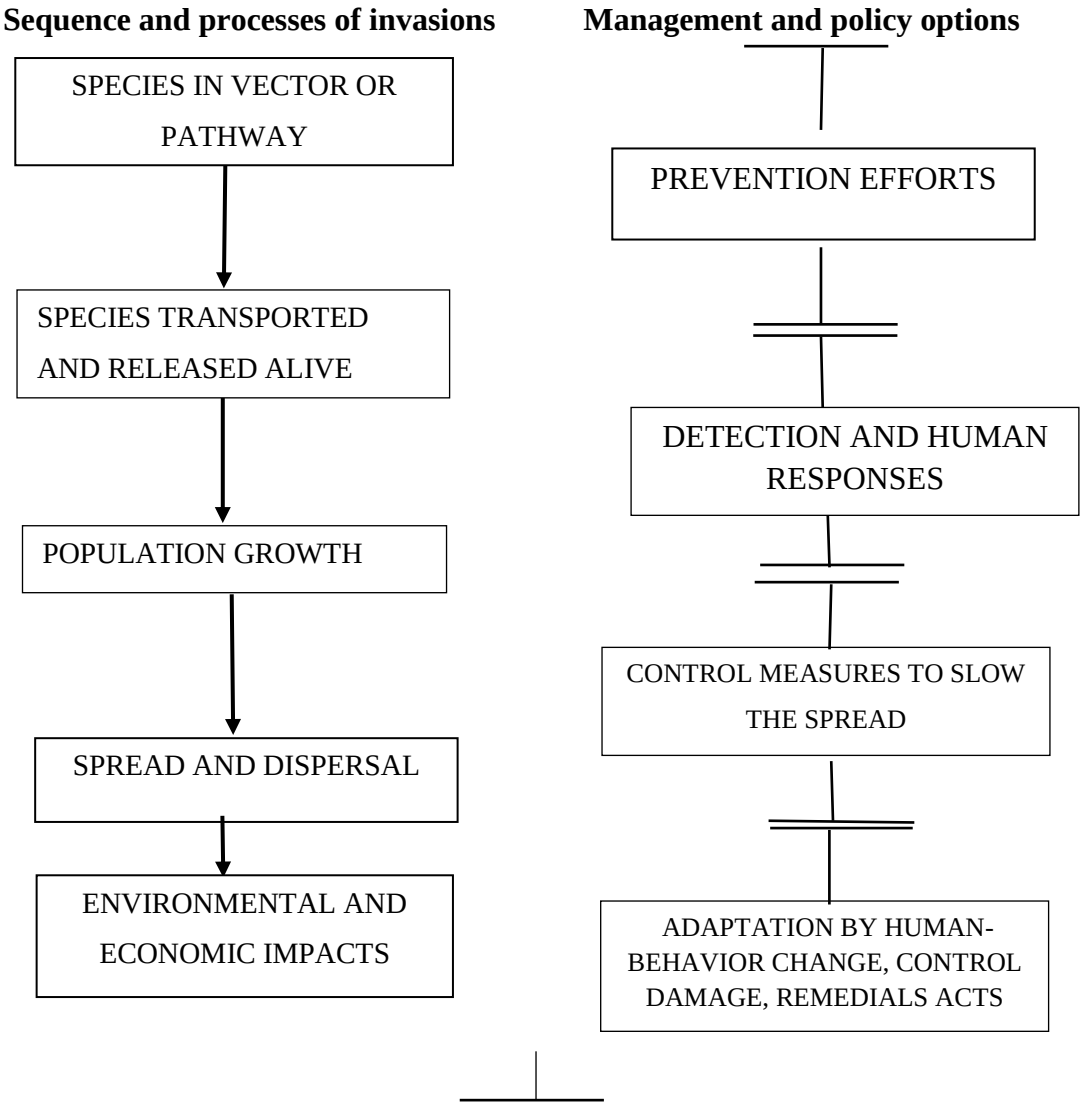

Figure 2.1: *Flow chart of biological invasions of invasive species*
Source: Marbuah et al. (2014: Pg., 503).

Biological invasion processes have been described to include; introduction, establishment, naturalization and spread or dispersal of invasive species and their damage creation. On introduction, species are transported from their native ranges with or without intentions through means and routes. They are then introduced to a new environment. When growth and fecundity allows increase in population of invasive species, they spread and establish within and outside the area of introduction. In the final stage of damage creation, the species cause substantial damage to the ecology, health of human and socio-economic systems. They impact on native species causing local extinction and shifts in structures and functioning of a community of organisms. In the invasion pathway, management strategies for the decision and policy maker includes; prevention, early detection, rapid response and eradication through manual and chemical means, control or mitigation and human adaptation to

2.9 The Conceptual Framework of the study

The invasive species and their impacts are regarded as independent variables. The outcomes of the socio-economic and environmental impacts of invasive species plants are regarded as dependent variables. Their value depends on the impacts caused by the invasive species. Figure 2.2 describes the relationship that exists between the dependent and the independent variables in this study. The main assumption is that there is a relationship between variables, however there is the influence of the intervening variable on the relation.

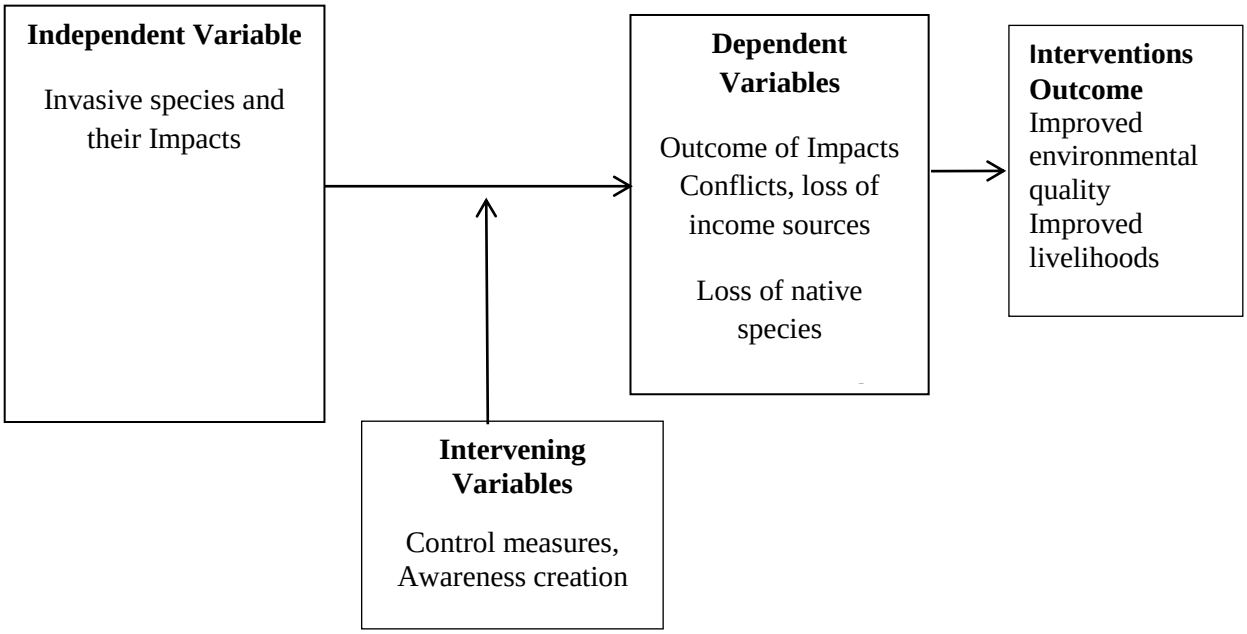

Figure 2.1: *Conceptual framework of the study*
Source: Author (2023)

The stronger the independent variable (population of invasive species and their impacts) because of the absence, weak or non-effective intervention measure (intervening variable) the more the impacts of invasive species and the greater the severity or magnitude of their impacts (independent variable). The strength of the severity of these impacts is manifested in socio-economic and environmental outcomes of the impacts (dependent variable). Socio-economic outcomes may manifest as loss of income, livestock and increase in resource use conflicts and species extinctions for environmental impact outcomes. These impacts will further depend on effectiveness of a method of intervention (Intervening variable). Presence, effective and timely interventions of the invasive species to weaken their strength will reverse the population of the invasive species and therefore, reduce their impacts and their severity outcomes over space and time. This will lead to increased flow of ecosystem goods and services due to improved environmental quality. This on the

other hand will benefit the resident community dependent on the environment leading to improved livelihoods (Author, 2023).

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter gives an overview of the physiographic, demographic, socio-economic and environmental characteristics of Samburu County within Kenya as it narrows to the sub-locations of Samburu East Sub-County where the study was undertaken. It further details the study methodology employed to attain the objectives of the study.

3.1 Study Area

Samburu County is one of the 47 counties in Kenya. It has three sub-counties namely, Samburu Central, Samburu North and Samburu East (Constitution of Kenya, 2010). It is mainly an ASAL and covers approximately 21,022.01km^2. It lies between latitude $00^0$30'N and $02^0$45'N, and longitude $36^0$15' and $38^0$10'E. Average elevation is 900m to 2500 metres above sea level (Samburu County Government, 2018). Bordering counties include; by Baringo and Turkana to the West, Marsabit to the North, Isiolo to the East and Laikipia to the South. Annual precipitation ranges from 400 mm to1250 mm; Temperatures are 18^0C to30^0C. Eight percent (8%) of the County receives sufficient moisture which supports rain fed agriculture. The rest of the County (92%) is arid and Semi-Arid Land **(**CGS, 2015**).**

The study was undertaken in the sub-locations of Samburu East Sub-County which is located in the eastern parts of Samburu County. Table 3.1 illustrates the administrative units, population of households and surface area occupied by the sub-county. It has 3 sub-counties (Divisions), 12 Locations, 29 Sub Locations, 181 Villages and 17,307 House Holds.

Table 3.1: Area and Administrative Units of Samburu County

S/No.	Name of Sub-County	No. of Wards	Area (Km^2)	No. of Sub-locations
1.	Samburu West	5	3,937.3	33
2.	Samburu East	4	10,049.7	29
3.	Samburu North	6	7,035. 01	46
Total	**3**	**15**	**21,022.01**	**108**

Source: County Government of Samburu, County Integrated Development Plan (2018)

The Sub-County is dominantly a rangeland covering 10,049.7 Km^2 with a population of 77,994 people and an average density of Eight (8) persons per km^2 (KPHC, 2019).

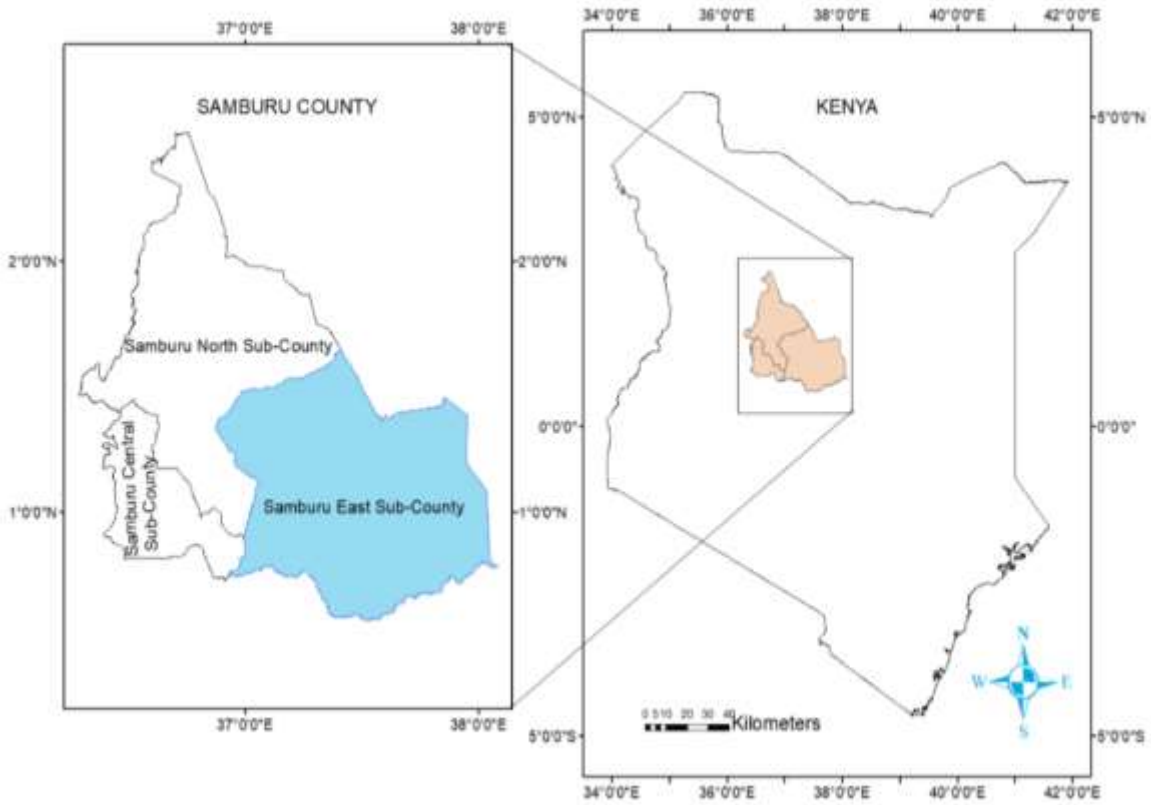

Figure 2.1: *Map showing location of Samburu East Sub-County*
Source: County Government of Samburu CIDP (2018).

It lies between Latitudes 00^0 33' N and 01^0 38'N and Longitudes 36^0 55' E and 38^0 03' E. It is dominantly occupied by Samburu pastoral community. The average range in altitude of the Sub-County is, 900 to 2500 m a.s.l, with few hills, one forest ecosystem (Mathew's ranges), home toSamburu National Game Reserve and eight community wildlife conservancies under the umbrella of Northern Rangeland Trust. Main wildlife found are; Lions, chetaahs, leopards, elephants, buffaloes, oryx, impalas, eland, reticulated giraffe, gerenuk, wild dogs, hyena and the Somali ostritch. It is described as arid and semi-arid climate with mean annual rainfall of 354 mm. The days are hot while the nights are cool with mean temperatures ranging between 18^0 C to 30^0C (Samburu CIDP, 2018).

The moisture index is 42-57, indication that evapo-transpiration is greater than available Moisture. It is drained to the south by Ewaso Ngiro North River. Except for ecosystems such as; forest, hills and riparian reserves, the soil moisture availability is low to very low. The soils are weakly developed, mostly sandy, low in organic matter and are saline in some parts of the Sub-County.

The vegetation is tropical Savanna with distinct proportions of open grassland and perennial herbaceous and woodland vegetation. The key vegetation types are Acacia-Commiphora small leaved deciduous woodlands of key species; *Vachelia reficiens, Vachelia tortilis, Vachelia seyal* Del., *Vachelia paolii, Hyphaene compressa* H.Wendl., *Senegalia senegal, Senegalia melifera, Boswellia hildebrandtii* Engl., *Cordia sinensis, Cordia quercifolia, Salvadora persica, Sansevieria intermedia, Sansevieria ehrenbergii, Cissus rotundifolia* and *Commiphora africana (*A.Rich.) Engl. Other key species include; *Boscia coriacea* Pax, *Maerua angustifolia* A.Rich, *Newtonia hildebrandtii* (Vatke) Torre, *Melia volkensii* Gurke, *Aloe secundiflora* Engl., *Aloe scabrifolia* L.E Newton & Lavrnos, *Lanea schimperi* Hochst. Ex (A.Rich)

Engl. *Balanites orbicularis* Sprag. *Balanites aegyptiaca* (L.) Del., *Grewia bicolor* and *Grewia tenax, Ipomea spanthulata, Calotropis procera, Duosperma crenatum* and a variety of grass species (Table 4.16 b*).* The forest ecosystem is composed of *Juniperus procera* Hochst. Ex. Endl., *Olea africana* Mill. *Osyris lanceolata* Hochst. & Steud, *Ficus thorningi* Blume, *Ficus wakefield*ii Hutch. *Ficus natalensis* Hochst and *Arundinaria alpine* K. Schum. Key exotic species are *Prosopis juliflora, Senna siamea, Opuntia ficus indica* and *Opuntia exaltata* (Samburu DEAP, 2012). Other species nomenclature authority is shown in Table 2.2 and Table 4.5.

Water availability in the study area is low, food availability is uncertain and the economic mainstay of the resident population is nomadic pastoralism. Wildlife rich areas have been planned and set aside as community wildlife conservancies. These conservancies have promoted eco-tourism as a viable bioenterprise for income and employment creations. The land tenure is mainly communal (County Government of Samburu CIDP, 2018).

The Sub-County is home to a number of wildlife species of worlds' conservation concerns and chiefly endangered species under CITES. Key environmental issues are; human-wildlife conflicts, land degradation mainly soil erosion, habitat loss, invasive plant species and drought (Samburu DEAP, 2012).

The sub-county was targeted because of the reported concerns posed by invasive plant species compared with the rest of the two sub-counties.

3.2 Research Design

Sequential explanatory mixed-method study design was used in conducting this study as suggested by Wakjira et al. (2022) for studies on collection of quantitative and qualitative data. This involved collection of data from household heads within the

Ultimate Sampling Units (all sub-locations of the sub-county), Key Informants and Focus Group Discussions using structured research instruments. Probability and non-probability sampling methods were employed to capture data within the sampling frame Fig. 3.2

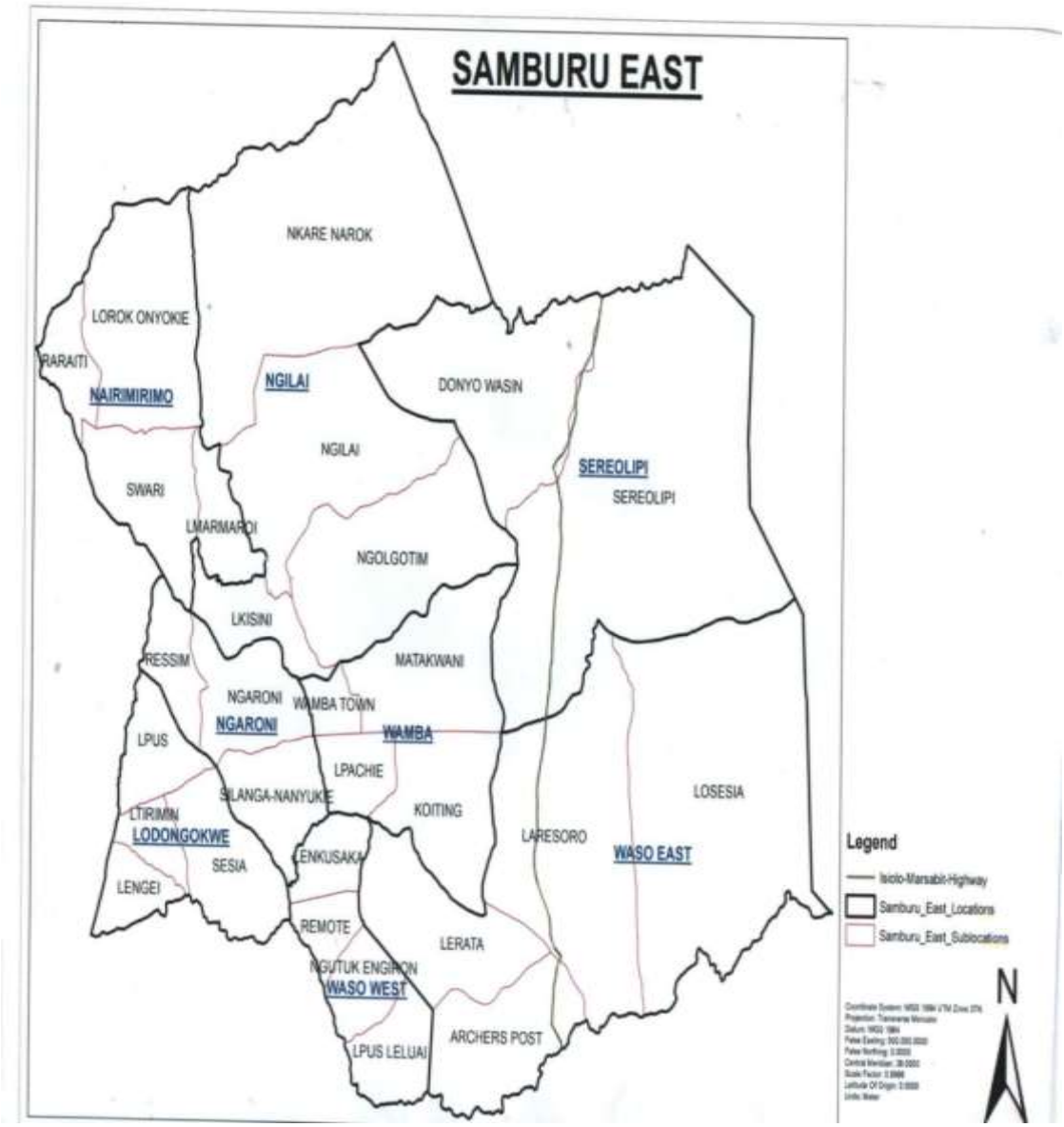

Figure 3.2*: Map of the Sampling Frame for the Study*

3.3 Target Population

The population targeted was 17,703 households being the total number of households in the sub-county. The study obtained information from a representative sample of

138 household heads from this total population of households' heads in the sub-county. Qualitative data was obtained from three (3) purposefully Selected Focus Group Discussions (FGD)-one each representing a division and ten (10) Key Informants (KI) drawn from the entire sub-county. The three categories of respondents were targeted because they were considered to have interacted with the species and are decision makers in the society.

3.4 Sampling Method and Procedure

Sampling size for the household heads was determined using Kalton (2009) formula and multistage clustered random sampling was used to obtain Ultimate Sampling Units (all the sub-locations). Systematic sampling was then used to get to the desired household heads in each sampled sub-location at a fixed rate of ten (10) household heads. Purposive sampling was used to get representative sample for qualitative data through three (3) Focus Group Discussions and ten (10) Key Informants..

3.4.1 Sample size determination and sample specification

The formula by Kalton (2009) was used to determine the study sample size with a confidence interval of 95%. The two plants of focus have existed in the administrative unit for a minimum of 43 years and 33 years respectively. Due to their spread and establishment in the Sub-County, concerns of the spread has been a community concern and some efforts have been locally directed to mitigate their impacts. Due to this long existent, concerns and efforts in place to control, the study assumed that all the respondents were aware and knowledgeable on the species invasiveness. Further the resident community predominantly practices nomadic pastoralism and is dominantly of Samburu ethnicity. Due to these community's substantial interactions

with the plant and homogeneity aspects, the study assumed a minimum variability of 10% as suggested by Kalton (2009).

$$ME = z\sqrt{\frac{p(1-p)}{n}}$$

$$n = \frac{p(1-p)z^2}{ME^2}$$

Where:

ME is the desired margin of error (95%) CI, α = 0.05, z is the desired z-score (1.96 for a 95% CI) yielding the desired degree of confidence, *p* is an estimate of the population proportion and *n* is the sample size.

$$\boldsymbol{n} = \frac{0.1(1-0.1)1.96^2}{0.025} \quad \mathbf{= 138.29 \quad = 138}$$

The he sample size (*n*) derived was 138 households. These was the representative sample for the study. Therefore, this was the number of households Heads interviewed in the study area (Table 3.3a-3.3c).

Table 3.2 (a*): Sereolipi Division Proportionate Population for the Study*

	Location (PSUs)	**Sub location (SSUs)**	**Sub location (USUs)**	**No. Of households/ Proportionate Population**	**Sample Allocation**	**Focus Group Discussion**
	1.Donyo Wasin	1.Donyo Wasin	1.Donyo Wasin	1036	15	
	2.Sereolipi	1.Sereolipi	1.Sereolipi	720	10	x
Total	**2**	**2**	**2**	**1,756**	**25**	

Source: Administrative units and population, KPHC (2019), Sample allocation (Author, 2023)**.**

Table 3.2 (b)*:* Wamba Division Proportionate Population for the Study

	Location (PSUs)	Sub location (SSUs)	Sub location (USUs)	No. Of households/ Proportionate Population	Sample Allocation	Focus Group Discussion
	Lodung'okwe	Lengei	Lengei	300	4	
		Lpus	Lpus	259	4	
		Ltirimin	Ltirimin	288	4	
		Sesia	Sesia	583	8	x
	Wamba	Matakwani	Matakwani	786	11	
		Wamba	Wamba	1834	27	
	Ngilai central	Ngilai central	Ngilai central	1092	16	
	Ngilai west	Lgolgotim	Ngolgotim	593	9	
		.Lkisin	Lkisin	614	9	
Totals	**4**	**9**	**9**	**6,349**	**92**	

Source: Administrative units and population, KPHC (2019), Sample allocation (Author, 2023)

PSUs-Primary Sampling Units (Locations) **SSU**s-Secondary Sampling Units (sub-locations) USUs-Ultimate Sampling Units (Sub-locations)

Table 3.2 (c*):* Waso Division Proportionate Population for the Study

	Location (PSUs)	Sub location (SSUs)	Sub location (USUs)	No. Of households /Proportionate Population	Sample Allocation	Focus Group Discussion
	Waso west	1.Lengusaka	1.Lengusaka	232	**3**	
		2.Lerata	2.Lerata	203	**3**	**x**
		3.Lpus leluai	3.Lpus leluai	584	**8**	
		4.Ngutuk Eng'iron	4.Ngutuk Engiron	234	**3**	
		5.Remote	5.Remote	277	**4**	
Totals	**1**	**5**	**5**	**1,530**	**21**	

Source: Administrative units and population, KPHC (2019), Sample allocation (Author, 2023)

3.4.2 Sampling design, procedure and scope

The study area is vast and the population where the samples were obtained is geographically spread thus Multistage sampling technique was employed to divide the population into smaller groups to simplify data collection exercise. This allowed the study to secure probability sample without complete sampling frame. Multistage clustered random sampling was used to determine the sample design frame at each stage of sampling, by clustering the locations and sub-locations and randomly selecting 50% of the administrative units at each stage. Households' Heads in each of the Ultimate Sampling Units were interviewed to get data for the study as per sample allocated per Ultimate Sampling Units. Household heads within each USUs were systematically selected at a fixed rate, whereby every 11th Household Head was included and interviewed as per interview schedule developed (Appendix IV).

Three (3) Focus Group Discussions using structured discussion guide were done after interviewing the selected households by randomly selecting three sub-locations, one each from the locational Ultimate Sampling Units of each division for the discussions as per the interview schedule for the discussions. This was to ensure that each of the administrative divisions are represented in the Focus Group Discussions. Each Focus Group Discussions comprised of 6-8 household heads and adult persons drawn from both gender who were knowledgeable on invasive species residing in the area. Discussants of the Focus Group Discussions were purposefully selected. The guide was structured to have open-ended-esay type questions for discussions on socio-economic activities of residents and environmental characteristics of the sub-location, their knowledge of and interactions with invasive species, their impacts and management interventions in the sub-location (Appendix, II). The number was informed by the suggestions of O.Nyumba et al. (2018) who adopted the work of

Krueger and Casey (2002), that 6-8 members of a Focus Group have generally been accepted as sufficient for the discussions.

Ten (10) Key Informants as suggested by, Muellmann et al. (2021) to be a sufficient number for Key Informants in a study, were drawn from relevant government agencies, NGOs, CBOs and senior citizens who are members of the County Environment Committee dealing with environmental management in the Sub-County and having various special information and experience on the management of invasive species were purposefully selected using a checklist of their relevance to the subject matter (Appendix III) and interviewed one month before the household heads interviews.

Table 3.3 (a): Multistage Sampling of Waso Division Administrative Units

S/no	Division	Location (PSUs)	Sub location (SSUs)	Sample allocation (USUs)	No. Of households
2.	Waso Division	1.Waso East	1.Archer's post		2016
			2.Lare soro		252
			3.Losesia		182
		2.Waso West	1.Lengusaka	1.Lengusaka	232
			2.Lerata	2.Lerata	203
			3.Lpus leluai	3.Lpus leluai	584
			4.Ngutuk Engiron	4.Ngutuk Engiron	234
			5.Remote	5.Remote	277

Source: Kenya Population and Housing Census (2019), Sampling (Author, 2023)

Table 3.3 (b): Multistage Sampling of Sereolipi Division Administrative Units

S/no	Division	Location (PSUs)	Sub location (SSUs)	Sample allocation(USUs)	No. of households
3.	Sereolipi Division	1.Donyo Wasin	1.Donyo Wasin	1.Donyo Wasin	1036
		2.Sereolipi	1.Sereolipi	1.Sereolipi	720

Source: Kenya Population and Housing Census (2019), Sampling (Author, 2023)

Table 3.3 (c): Multistage Sampling of Wamba Division Administrative Units

S/no	Division	Location (PSUs)	Sub location (SSUs)	Sample allocation (USUs)	No. Of households
1.	Wamba Division	1.Koiting	1.Koiting		592
			2.Lpashie		316
		2.Nkaroni	1.Nkaroni		613
			2.Resim		386
			3.Silango Nanyekie		432
		3.Lodung'okwe	1.Lengei	1.Lengei	300
			2.Lpus	2.Lpus	259
			3.Ltirimin	3.Ltirimin	288
			4.Sesia	4.Sesia	583
		4.Nairimirimo	1.Lmarmaroi		371
			2.Lorok onyekie		658
			3.Raraiti		269
			4.Suari		898
		5.Nkare Narok	1.Nkare Narok		687
		6.Wamba	1.Matakwani	1.Matakwani	786
			2.Wamba	2.Wamba	1834
		7.Ngilai central	1.Ngilai central	1.Ngilai central	1092
		8.Ngilai west	1.Ngolgotim	1.Ngolgotim	593
			2.Lkisin	2.Lkisin	614

Source: Kenya Population and Housing Census (2019), Sampling (Author, 2023)

3.5 Data Collection

3.5.1 Research instruments

Data collection tools were developed and structured based on extensive literature reviews on adequate background information on invasive plant species and information from Key Informants. This was subjected to experts' opinion on their alignment and suitability to the study design, sampling design and suitability to capture data accurately and precisely for the study variables.

Household questionnaires and Key Informants Guides were designed and structured into four sections to capture preliminary information of the administrative units, respondents' location of residence, their contacts and dates of the interviews.This was preceded by consent and confidentially note read to respondents before the interview. Section A; captured respondents' bio data, history of their stay in the sub-locations and socio-economic characteristics; Section B, on respondents' general information on environmental characteristics of the environment, knowledge of invasive species and their impacts in the sub-location; Section C, on specific impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio-economic activities and selected components of the environment and Section D, on management interventions on the two species and recommendations for sustainable management of the invasive species (Appendix II). Key socio-economic activities and environmental components, five each were selected through listing and pairwise ranking of responses obtained from Key Informants.

Questionnaires contained closed-and-open ended, dichotomous yes-and-no questions some with Likert scale ordinal scaled questions with confirmatory or explanatory questions to precisely obtain quality data for the study. Questions were structured to

capture Likert scale questions as guided by Likert excerpts from Joshi et al. (2015). Likert scale questions had a provision for rating 'Yes' and 'No' answers. The questionnaire was pre-tested before use to confirm its validity, reliability and sutability for the study. Interview guide for the Key Informants was structured to capture similar information as that of household head questionnaires but Likert scale questions on impacts of the two spcies were not to be rated but prioritized from a checklist (Appendix II).

On Likert scale questions the respondents were asked to rate various aspects of socio-economic activities and components of environment impacted by the species based on a five- point Likert scale, where 0, indicated no impact ; 1, insignificant impact ; 2, minor impact; 3, moderate impact ; major; 5, severe impact (Appendix, V).

Focus Group Discussions guides were structured to have open-ended-essay type questions for discussions on socio-economic activities of residents and environmental characteristics of the sub-location, Discussants knowledge of and interactions with invasive species, impacts of the two species of focus, history of management interventions and recommendations in the sub-location (Appendix II).

3.5.2 Pre-testing of questionnaires

Questionnaire were piloted and pre-tested outside the study area before they were subjected to validity and reliability measurements. Seven Households Heads were randomly selected for interview using developed questionnaires in Soro Adoru Sub-Location, Samburu Central Division on 2nd June, 2022. The area lies outside the study area but has similar socio-economic and environmental characteristics of the study area.

Unique characteristics of the area were that it was an ASAL and main economic activity was livestock production and inhabited by the nomadic Samburu pastoralist community. This was done before the study was embarked on. To ensure quality of the data to be collected, Matters and Errors that arose during pretesting of questionnaires included length of the questionnaire and spelling errors. This necessitated reductions of the number of questions and number of questionnaires per Enumerator per day to three only and typo errors were rectified too. Duration of the interview for each household was also increased from the planned one hour to two hours per household head interview.

3.5.3 Determination of questionnaires Validity

To ascertain how valid the pre-tested instrument were, the Kaiser-Meyer-Olkin (KMO) was used. This gave a Measure of the Sampling Adequacy computed from the factor analysis test as suggested by (Field 2009). This was derived from SPSS version 26. The factor loading was computed as 0.847 which was seen to be above the threshold of 0.4, hence the questionnaires was considered valid for use in data collection.

3.5.4 Determination of the Reliability of questionnaires

Reliability is a measure of the degree to which a research instrument yields consistent results of data after replications (Richardson et al., 2015), Reliability of the questionnaire was determined using the internal consistency value determined using SPSS version 26. The acceptable range for alpha internal consistency value (r) is 0.70 and above (Ayala & Elder, 2011).

The Cronbach alpha reliability for measuring internal consistency was computed using SPSS version 26. In this study all the seven questionnaires for the pilot were

coded into the SPSS and using the internal consistency option the reliability for the entire questionnaire statements was computed. The results showed a reliability coefficient of 0.891 for the 33 items indicating that the questionnaire was reliable and hence appropriate for collecting the required data.

3.6 Administration of Research Instruments

3.6.1 Reconnaissance survey

Adequate reconnaissance surveys and site inspections prior to data collection exercise with the assistance of sub-locations' administrative officers and village elders additionally preceded data collection exercise. This was in order to get acquainted with the residents, geography of the area and settlement patterns of the resident community. This further aided the identification and training of research Assistants and enumerators for the study and securing cooperation with the sub-locations' leadership and populace. This opportunity was also used to identify and assess settlement patterns of the households for listing and alignment with the sampling design of the study.

3.6.2 Data collection methods

An interview schedule was developed before data collection commenced for each category of the respondents. This was important to make sure that data collection was consistent and covered target population for the study. Research instruments were administered as per the sampling design, procedure and frame as in 3.4.2.

Face-to-face method of interview was employed to capture data from the three categories of respondents. Capturing of responses entailed pencil-and-paper recording of the responses using structured instruments. Data collection exercise was done during the onset of the dry season when vegetation of the study area had most plants

flowering and some have started fruiting. In the season local populace were settled in their sub-locations as pasture and water were available. The collected data using questionnaires within a period of one month was used to draw statistical inferences for the study.

3.7 Statutory Ethical Considerations

Mandatory regulatory authorizations were secured from the statutory entities relevant to the research as follows; Maasai Mara University Supervisors , Department of Environmental Studies, Geography and Agriculture, School of Natural Resources, Tourism and hospitality and School of Post Graduate Studies of Maasai Mara University,Samburu County Government, Lead GOK Agencies-,Ministry of Education, Ministry of Interior and Coordination of National Government, and National Commission for Science, Technology and Innovations prior to the undertaking of the research (Appendix I).

Prior informed participant's consent was secured from the survey respondents on a written introductory letter which was read out before respondents were engaged for the interview. Rapport building during reconnaissance survey and inspections were also done. Utmost anonymity and confidentiality of the data and information of the Study was assured and adhered to through communication and rapport building to the target population, discussants and Key Informants.

3.8 Data Processing, Presentation and Analysis

Descriptive and inferential statistics was used to present and analyze the collected data respectively. Data from the respondents was coded, entered in excel sheets and piloted to ensure that coding was appropriate. The data contained in the excel sheet was entered into SPSS version 26. Logical checks were used to validate the inputted

data. To identify major themes and dominant narratives, qualitative data from the interviews were coded and indexed through intensive content analysis. Quantitative data was analyzed using frequencies and percentages. Statistics were summarized and exported to excel worksheets. Tables and graphical figures were produced from the worksheets and used for analysis and interpretation.

Likert scale data mean impacts values was computed by taking the sum of the product of the actual response on each value of the scale and dividing by the number of respondents interviewed in the sub-county for objective 1 and 2 and in each of the division for objective 3 as shown in the below formula adopted from Chun (2021) and Shin et al. (2018).

Mean Score = $\sum$ (f_i x Likert item score) ÷ Number of respondents

Inferential analysis was computed to test whether the impacts were statistically significant or not, this was tested using the 5% significant level. Cross tabulations was done to test the Pearson's Chi Square test which assisted to determine whether there was an association between the variables; socio-economic and environmental impacts and spatial variations of impacts.

3.9 Dissemination and Utilization of Research Output

Upon approval, the outcome of the study will be disseminated to as published information in referred journals and publications for utilization by Maasai Mara University, the sponsoring entity, government agencies, scholars, policy makers, NACOSTI, researchers, rangelands actors, natural resource managers and County Government of Samburu for consideration and incorporation in sustainable management of invasive plant species in the Sub-County and by extension the county.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents the results of the analysis based on the data obtained from household heads interviewed in three sections; Section one discusses the response rate from the survey, two the social and economic characteristics of the households, and section three presents the results of the data obtained on impacts of the species as responded by household heads, Key Informants and Focus Group Discussions in line with the four objectives of the Study.

4.1 Respondents Response Rate

The study captured data from a total of 138 household heads residing in the study area. All the 138 questionnaires dully filled and verified, were collected for the analysis. The analysis indicated a 100% response rate. Three Focus Group Discussions were held along with household heads interviews. Ten Key Informant Interviews preceded the study. On the analysis of the objectives only 122 heads of household questionnaires representing 88.5% were analyzed as the species were reportedly existent in the sub-locations. The two species of focus were reported by 16 respondents representing 11.5% of the total respondents in the study area, as not present in the sub-locations, therefore not considered during data analysis for the four objectives.

Thus out of 16 sub-locations only 15 representing 93.8% of the sub-locations reported the presence of the two species. The high response rate was attributed to constant follow-up of enumerators by the researcher and field Assistant. The questionnaires were all verified to assess the effectiveness of their use for the analysis and they were

found appropriate. The response rate was in line with Mugenda and Mugenda (2003), Babbie and Rubin (2010), and Babbie (2010) recommendations on a response rate of above 70% being suitable for data compilation and analysis.

4.2 Socio-Economic Characteristics of Households

Background information of the respondents per sub-location was obtained and analyzed based social and economic attributes such as; gender, age bracket, marital status, and the number of Years heads of households had lived in the area. Further, economic activities practiced and the major threats facing the households in the area, in reference to their socio-economic activities and the environment they live in the sub-locations were also obtained.

4.2.1 Gender of the respondents

It was important to assess perception and opinion from both male and female respondents as gender is an important social factor in a society. Gender distribution of the respondents is presented in Figure 4.1.

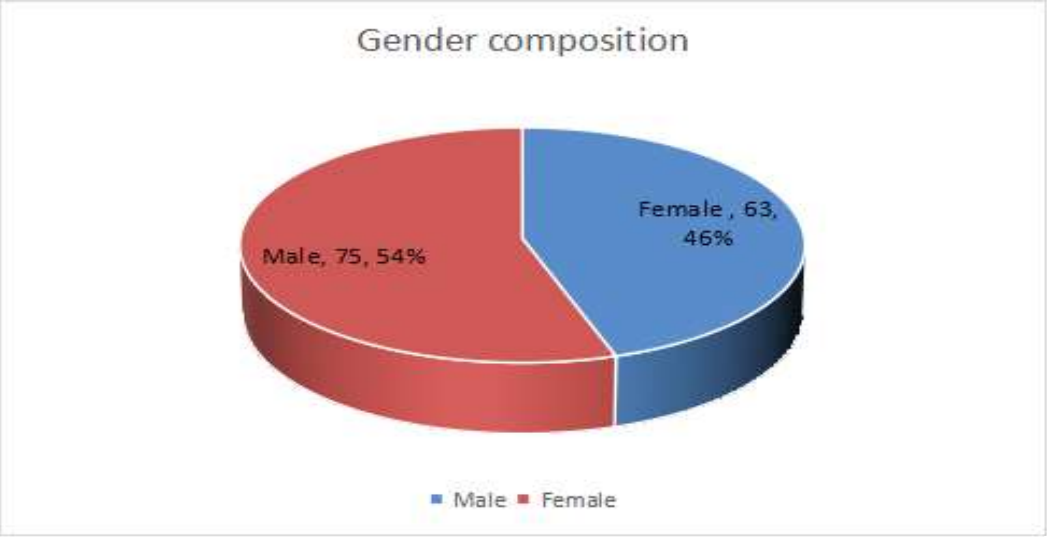

Figure 4.1: *Gender distribution of the respondents*

The results show that, 75 of the respondents (54%) were male and 63 (46%) being female. This implies that, majority of the participants in the study were male who are

the head of the household. This is a patriarchal region where the male makes all important decisions of the family.

4.2.2. Age distribution of the respondents

The age of the respondents was considered very important as it helps to assess the experiences and knowledge of household heads targeted in regard to the objectives of the study. Distribution of respondents by age is presented in Figure 4.2.

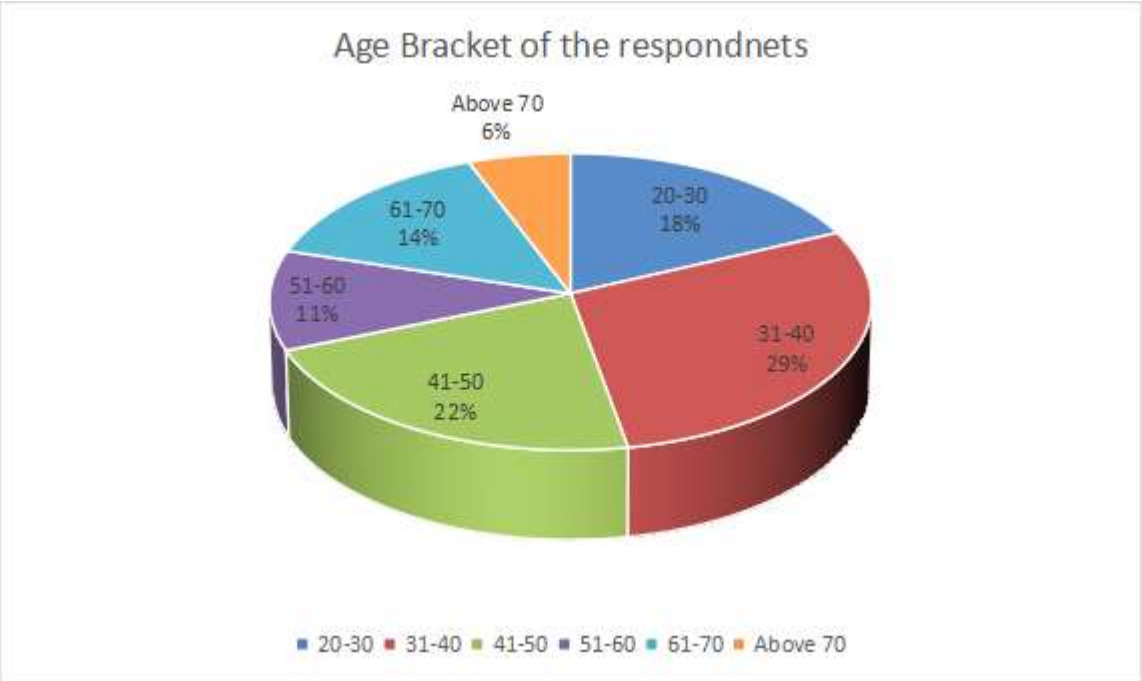

Figure 4.2: *Age distribution of the respondents*

Results show the respondents' distribution among age brackets as; 29.0% were aged 31-40 years, 22.0% aged 41-50 years, 18.0% aged 20-30 years and 14% in the age bracket of 61-70 years, 11% were in the age bracket of 51-60 years and the rest 6.0% were aged above 70 years. This shows a well-represented sample with over 80% of the respondents being above 30 years and that all the respondents (100%) were adults able to make decisions. This implied among household heads, an understanding of the previous and current situation in terms of socio-economic and environmental aspects

as they relate to invasive plant species and how the species have impacted on the population and the environment of the sub-locations in the Sub-County.

4.2.3 Level of education of the respondents

Education is an important social factor that influences the perception of the respondents in regard to the aspects of change in the environment and their effect on the population in the study area. The assessed responses are presented in Table 4.1.

Table 4.1: Responses on the Educational Level of the Respondents

Educational level	Frequency	Percentage
Primary	19	14%
Secondary	19	14%
Tertiary	5	3%
None	95	69%
Total	**138**	**100%**

Source: Author (2023)

The results show that most of the respondents 69% had no formal education, 14% had attained primary education, 14% had attained secondary education and only 3 % of the participants had attained tertiary education. This implies that most of the people in the area who participated in the interview had not attained any formal education. This was attributed to the fact that few residents had accessed formal education indicating that literacy levels were very low in the sub-county. It was also noted that most of these respondents had experiences based on their inert knowledge which was still very important for this study. This was important and justified the use of research Assistants and Enumerators who were residents and had the local dialect of the resident community.

4.2.4 Marital status of respondents

The study also sought to establish the marital status of the respondents as it is the unit that forms the household. The results are presented in Figure 4.3.

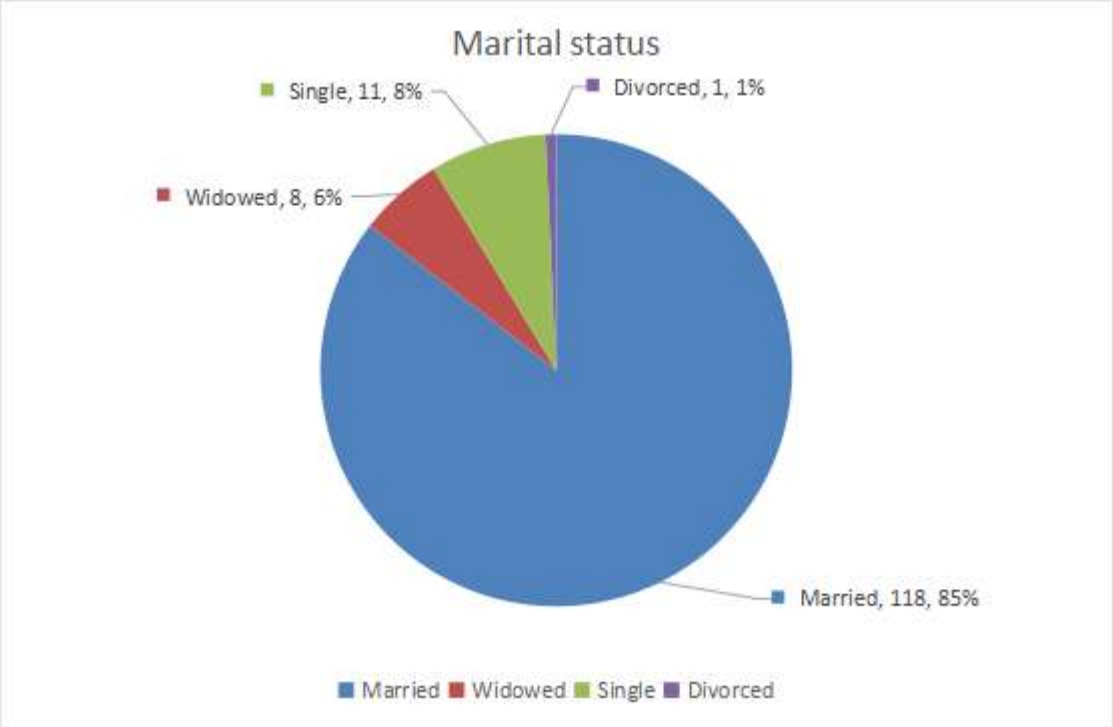

Figure 4.3: *Marital status of the respondents*

The results show that most of the respondents, 85.0 %, were married, 8.0% were single, and 6.0% were Windows or widowers, while the rest 1% were either divorced or separated.

4.2.5 Hierarchy of respondents in the household

The study aimed to establish the head of the household as it was important to get data from the persons of authority as targeted by the study. The results are presented in Figure 4.4.

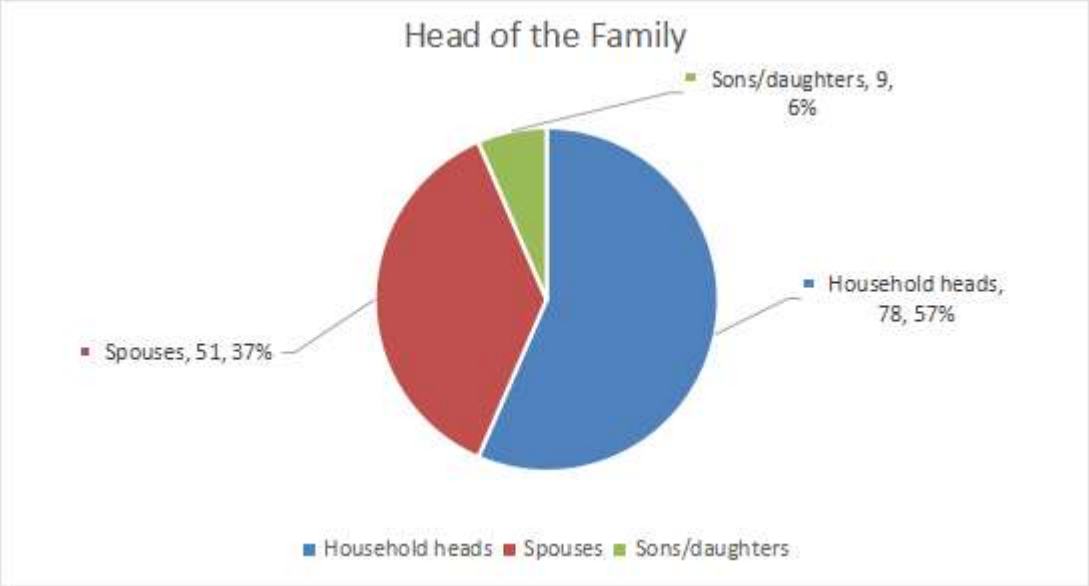

Figure 4.4: *Hierarchy Distribution of the household heads*

The results in Figure 4.4 shows that majority of the respondents, 56 % who responded from the household were the fathers or mothers who are the heads of the family, followed by 38% who were mothers and the rest 7 % were children from the households. This showed that fathers or mothers were in the forefront to respond positively to the study.

4.2.6 Number of years the respondents lived in the sub-location

The study had to establish the number of years the respondents had lived in the area. This was important as it helped to determine whether the respondents understood the changes that have taken place if any. The results are presented in Figure 4.5.

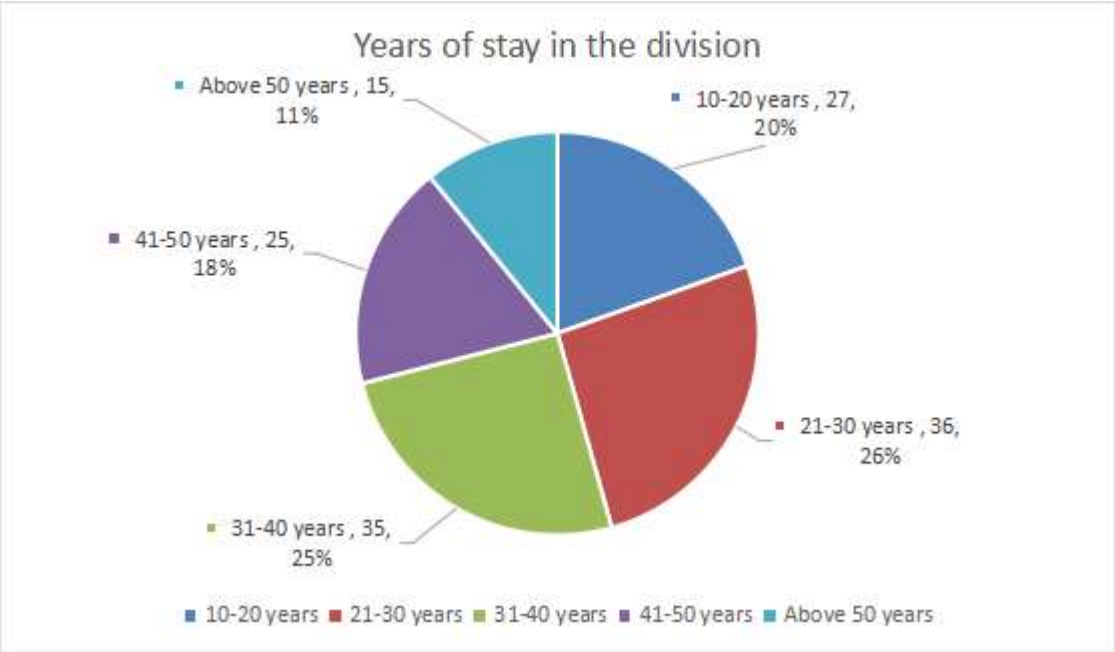

Figure 4.5: *Respondents years of stay in the sub locations*

Figure 4.5 shows that; 51.0% of the respondents have lived in the area for between 21-40 years, 20% lived between 10-20 years, 18 % lived between 41-50 years, and 11% lived in the area for more than 50 years. This implies that a majority of 80 % of the respondents have been in the area for more than 20 years and hence they are more likely to understand and interpret the environmental changes and various aspects of the socio-economic of the populace in the area.

4.2.7 Households' economic mainstay

The study sought to find out the various economic activities practiced by the households and also to assess the one that is mainly practiced by the majority of the households. The results are presented in Table 4.2.

Table 4.2: Responses on Households' Economic Mainstay

Economic Activities Practiced	Frequency	%	Main Economic Activity	%
Livestock production	136	98.6	128	92.8
Irrigated agriculture	21	15.2	1	0.7
Retail business	17	12.3	2	1.5
Ecotourism	2	1.4	0	0.0
Formal/informal employment	2	1.4	1	0.7
Sale of sand/ballast	3	2	1	0.7
Poultry keeping	23	16.7	3	2.2
Bee keeping	10	7.2	1	0.7
Charcoal burning	4	2.9	1	0.7
Totals			**138**	**100**

Source: Author (2023)

The results show that most of the households (98.6%) engage in livestock production as an economic activity, 16.7% indicated they engage in poultry keeping, 15.2% indicated that they practice irrigated agriculture while 12.3% indicated that they engage in business mainly retail. This implies that the main economic activity practiced among majority of the households is Livestock production. This is attributed to the pastoral nature of the people and also the nature of the climatic patterns in the area. The results on the table also shows that main economic activity in majority of the households in the sub- locations is livestock production as indicated by 92.8% of the respondents. This was followed by poultry keeping which accounted for only 2.2% and retail business at 1.5%. This clearly describes the pastoral nature and economic practice of the residents living in the area.

Similar responses were obtained from the Key Informants Interviews and Focus Group Discussions where the respondents indicated that their main economic activity

was livestock production. All the Focus Groups and KII respondents responded that their main economic activity was livestock production at 100%. They also noted that besides livestock production they also relied on ecotourism to earn a living, others engaged in Trade, wildlife conservation, beekeeping, poultry farming, mining and formal employment. This therefore, clearly show that livestock keeping was the major economic activity practiced in Samburu East Sub-County.

4.2.8 Major threats affecting economic mainstay of households

On economic mainstay, the study examined the factors influencing economic systems of the households. This was important in assessing the impact of these threats on the livelihood of the households. The results are presented in Table 4.3.

Table 4.3: Responses on Key Threats to Economic Mainstay

Economic Threat	Frequency	Percentage (%)
Soil erosion	30	7%
Drought	105	25%
Invasive plants	86	21%
Livestock diseases	91	22%
Human-wildlife conflicts	43	10%
Low/poor pasture and water availability	39	9%
Conflicts/insecurity	20	5%

Source: Author (2023)

The above results show that majority 25% of the respondents indicated that the major threats that the households are facing is drought , followed by livestock diseases, 22%; Invasive plants, 21% and human wildlife conflicts accounted for 10%, while Low/poor pasture and water availability accounted for 9%, soil erosion 7% and conflicts and insecurity accounted for 5%. This shows that the worst threats to

economic activities of the households in Samburu East Sub-County is drought, livestock diseases and invasive plant species.

On qualitative analysis, the respondents reiterated that residents and livestock need water for their survival. The conflicts that frequently arise in the sub-locations is caused by the competition for the water and grasslands and mainly they occur during drought. The human-wildlife conflict is not caused by any other causal agent but the demand for the little available water and fodder during prolonged drought periods in the area. The poor land cover by vegetation leads to flash floods and hence soil erosion.

On invasive species, infestations have worsened drought situation as they deplete the natural grasslands and make it very difficult for the grass to grow. Since they are not good fodder they have very great impact on the survival of the livestock. Their canopy becomes a good breeding place for harmful pests which cause diseases to both human and livestock. Their impenetrable thickets have interfered with free movements of people, livestock and wildlife. This has further heightened human-wildlife conflicts in the area. This agrees with the findings of Bufebo et al. (2018) on invasive species destabilizing social and economic systems in Ethiopia.

This was confirmed through the Key Informants and the Focus Group Discussion where most of the participants agreed that the main threat to their economic activities is drought, livestock diseases and invasive plant species.

4.2.9 Major threats affecting the environment of the sub-locations

The study further assessed the major threats afflicting the environment of the Sub-County as responded by household heads. The results are presented in Figure 4.6.

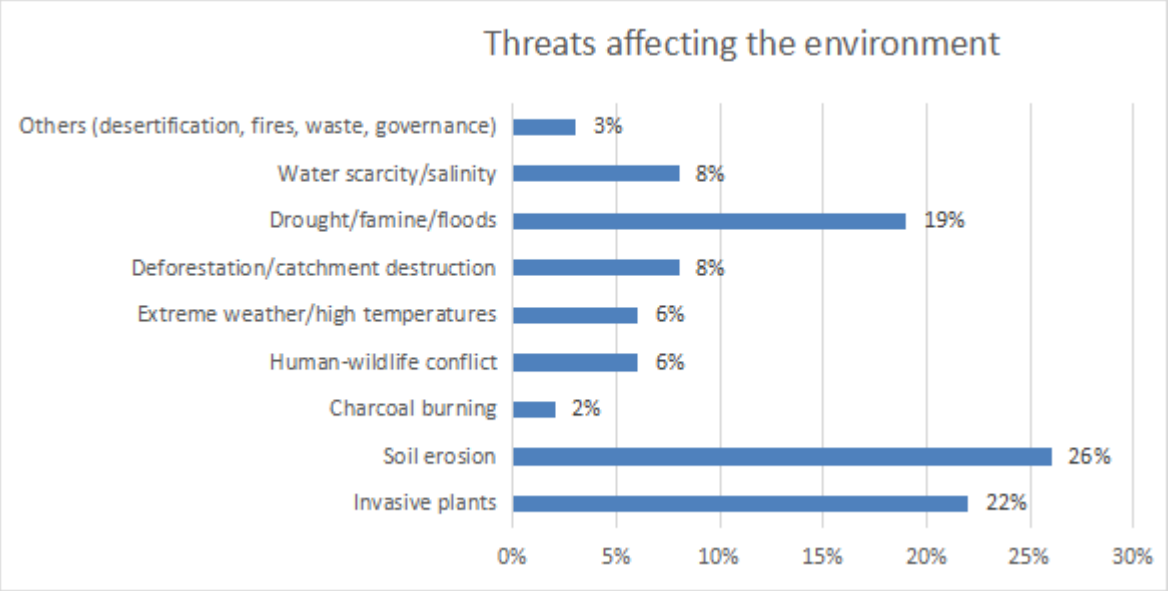

Figure 4.6: *Major threats affecting the environment of the sub locations*

The results show that soil erosion accounted for 26% of the threats to environment, followed by invasive plants which accounted for 22%, drought /famine /floods accounted for 19%. The results also showed that biodiversity loss accounted for 13%. This implies that the major threat affecting the environment was soil erosion. Water scarcity and salinity accounted for 8% and deforestation /catchment destruction which accounted for 8%. This showed that soil erosion was the major environmental threat in the area, followed by invasive species and drought respectively. This is attributed to the fact that most land is bear of vegetation and hence the soils are open to both flash floods erosion and normal erosion. The invasive plants just contribute to the destruction caused by soil erosion as they leave the land bear of vegetation. Deforestation which is as a result of cutting down the vegetation for use as firewood and for charcoal burning which is also considered an economic activity, has made the soil bare and hence soil erosion.

The responses from the Focus Groups and Key Informants interviews were also obtained. The respondents ranked the environmental factors in accordance to their impact. They noted that invasive plant species were considered to have the highest

impact in the Sub-County as indicated by 90% of the respondents. This was followed by soil erosion at 70%, land degradation at 40%, loss of biodiversity at 40%, charcoal burning at 40%, drought at 30% and human-wildlife conflicts at 30% while the rest were below 30%. This implies that just like the community interviews indications, soil erosion and invasive plants have a very high impact on the environment in the Study area. This was attributed to the realization that the invasive plants and soil erosion go hand in hand in the sense that areas with high level of invasive plants have high level of soil erosion because of the loss of land cover.

4.2.10 Types of the invasive plants in the sub-locations

Excerpts from Table 2.1 were used to develop a checklist of five key characteristics exhibited by plants perceived as invasive (Table 4.4). The checklist was subjected to household respondents to determine invasive plants in the sub-county. This was based on Key Informants ranking of them as applicable in the study.

The study sought to establish whether the residents were aware of the invasive plants in the area. This was collected using both household heads questionnaires and the Key Informant interview guides. The respondents were able to identify 8 more invasive species apart from *Vachelia reficiens* and *Prosopis juliflora* based on their descriptions of them as guided by plants' characteristics in Table 4.4.

Table 4.4: Characteristics of Plant Species Perceived as Invasive in the Sub-Locations

Plants characteristics	***Vachelia reficiens***		***Prosopis juliflora***	
	Yes	No	Yes	No
Unusual widespread distribution	90%	10%	100%	0
Dominates or smother other vegetation	40%	60%	100%	0
Risky to the health of humans and livestock	70%	30%	100%	0
Has negative impacts on grazing systems	100%	0	100%	0
Its thickets are unpassable	80%	20%	100%	0

Source: Author (2023)

The results showed that *Prosopis juliflora* has the characteristic of being wide spread as it grows and spreads very fast as compared to other vegetation including *Vachelia reficiens*. The results also showed that both species had a dominance and smother characteristics over other vegetation, hence making them invasive plants. On plant risks to health of human and livestock, majority of the respondents indicated both species to pose health risk to both humans and animals. On one front, thorns from *Prosopis juliflora* posed a health risk to both humans and livestock. *Prosopis juliflora* has a greater impact because apart from being a hiding place for predators, it also harbour pests, and has many other health related challenges.

The study also noted that majority of the respondents indicated that both species negatively impacts on the grazing systems. This is because in regard to *Vachelia reficiens* the canopy destroys the grass below and leads to erosion which depletes the soil, plants and grasslands. *Prosopis juliflora* on the other hand grows very fast and has impenetrable thickets which become appropriate traps for the cattle and this causes a great risk to the residents in terms of livestock predation by lions mainly.

Based on characteristics of invasive plants as in Table 4.4, the respondents were able to list a number of invasive plants they perceived as invasive other than the two species of focus. These are listed in Table 4.5.

Table 4.5: Plants Perceived as Invasive by Household Heads

Plant Species	Origin	Growth Form	Local Name (Samburu)	Frequency	%
Prosopis juliflora Swartz D.C	Ex	S/T	Ldalami/Masanduku	114	93.4
Vachelia reficiens (Wawra & peyr.) Kyal.& Boatwr	I	S	Lchurai	118	96.7
Senna acutifolia Delile	I	S	Seenetoi orok	16	13.1
Vachelia nubica (Benth.) Kyal.& Boatwr	I	S	Ldepe	1	0.8
Vachelia paolii (Chiov.) Kyal.& Boatwr	I	S	Lmartii	12	9.8
Senegalia melifera (M. Vahl.) Benth.	I	S	Iti	1	0.8
Senna occidentalis L.	I	S	Seenetoi	9	7.4
Sansevieria intermedia N.E.Br	I	Suc. H	Ldupa sorro	34	27.9
Sansevieria ehrenbergii Schweinf. Ex Baker.	I	Suc. H	Ldupai	25	20.5
Justicia striata (Klotzsch) Bullock	I	H	Sigiit/Ntitikole	101	82.8
Cissus rotundifolia Lam.	I	Climber	Raraiti	22	18.0
Ipomoea longituba Hallier f.	I	Tub. S	Loisiachi	18	14.8
Calotropis procera (Aiton.) R.Br.	I	S	Laibelechi	6	4.9
Ipomoea spanthulata Hall f.	I	S	Lokitengi	1	0.8
Solanum incanum L.	I	H	Ltulelei	5	4.1
Opuntia exaltata (A.Berger) D.R Hunt	E	Suc. S	Lkurasi	8	6.6
Opuntia ficus indica L.	Ex	Suc. S	Laibelechoi	8	6.6
Heliotropium steudneri Vatke	I	H	Lmasikirai	4	3.3

T-Tree **S-**Shrub **Suc.-**Succulent **H-**Herb **I-**Indigenous **Ex**-Exotic **Tub**.-Tuberous

Source: Author (2023)

The results show that apart from *Vachelia reficiens* and *Prosopis juliflora* which were considered for the study, other invasive plants of concern exists in the Sub-County.

These included, *Justicia striata* at 82.8%, *Sansevieria ehrenbergii* was also noted to have an impact as indicated by 20.5 % of the respondents followed by *Sansevieria intermedia* which was noted by 29.7%. This was followed by 18% and 14.8% who indicated that *Cissus rotundifolia* and *Ipomoea longituba* were of concerns in terms of their spread and establishments in the Sub-County.

Further analysis was done based on the results obtained from the KII responses. The KII results show that all (100%) of the respondents who participated in the interview indicated that *Vachelia reficiens* was an indigenous species and it was common in all the Divisions where the study was conducted. *Prosopis juliflora* was considered an exotic invading plant with 90% of the respondents indicating that it was found in the locality. The results show that other indigenous invasive plants found only in selected areas were *Cissus rotundifolia* with 20% response, Duosperma species with 10% response and Sanseveria species with 40% response. The results also show that there were other exotic invasive plants though their distribution and prevalence was only in few areas. It was noted that 20% of the respondents identified *Lantana camara* as an exotic invasive species, 20% also identified *Opuntia stricta* as being an exotic species, 10% identified *Senna didymobotrya* and 30 % identified *Opuntia exaltata* as being exotic. This indicates that *Vachelia reficiens* was among the widely spread indigenous invasive plant species in the sub-county while *Prosopis juliflora* was the most common and widely spread exotic invasive plant in the Sub-County. The study revealed that *Vachelia reficiens* in Samburu East Sub-County originated from a place called '*Talle'* in Isiolo County' (Author, 2023). This suggests that the plant was introduced to the Sub-County by dispersal agents from Isiolo County. Therefore, apart from *Vachelia reficiens* and *Prosopis juliflora*, there are twenty (20) other plant species perceived by the respondnets as invasive in the sub-county.

4.2.11 Year/s the invasive plant species were perceived to impact negatively

In order to establish the extent to which the invasive plants have been in the area and hence the impact it has caused to the residents in terms of socio-economic and environmental wellbeing, the respondents were asked to indicate the impact years of the invasive plant in the divisions. The results are presented in the Table 4.6.

Table 4.6: The Impact Year of Invasive Plants as Responded by Household Heads

Year	**Divisions**					
	Wamba		**Waso**		**Sereolipi**	
	Vachelia reficiens	**Prosopis**	**Vachelia reficiens**	**Prosopis**	**Vachelia reficiens**	**Prosopis**
1960,s	0	0	0	0	3	0
1970's	3	0	1	0	4	1
1980's	7	0	2	0	11	8
1990's	33	15	10	4	3	10
2000's	30	38	7	7	4	5
2010 & above	3	7	1	4	0	0
Mode	33	38	10	7	11	10
Year	**1990's**	**2000's**	**1990's**	**2000's**	**1980's**	**1990,s**

Source: Author (2023)

The results show that in Wamba, *Prosopis juliflora* has been known as an invasive plant since 2000 while *Vachelia reficiens* has been known since 1990. In Waso the results also showed that *Vachelia reficiens* has been known as invasive since 1990 while *Prosopis juliflora* has been known to be invasive since 2000. Sereolipi residents indicated that *Vachelia reficiens* has been known to be an invasive species since 1980 while *Prosopis juliflora* has been known to be invasive since 1990. This showed that

the species have been known to be invasive longest in Sereolipi. This was important for the study on the spatial temporal impacts of the two species.

On qualitative analysis of FGD responses, the result show that, *Vachelia reficiens* is the oldest invasive indigenous plant in the area whose impacts were felt between the years 1980- 1995. This implies that the plant is present in all the three division in the Sub-County. The results also showed that *Prosopis juliflora* which is an exotic invasive plant was introduced in the three division to halt degradation by GTZ and SDDP in the 1980s and 1990 respectively, however its impacts were felt in the area in 1990s and 1997. This clearly showed that both plants have been in existence in the area for at least 30 years. The other invasive plants which were also identified to have impacted for a long time are *Justicia striata* in 1997, *Ipomoea spanthulata* in 1990 and *Vachelia paolii* in 1980s as indigenous invasive plants. This clearly showed that the invasive plants have been present in the three division for a little longer and hence their impact on the Socio-economic activities and the environment among the residents is clearly known. Majority of the respondents linked the 1997 *El Nino* phenomemon to the increase in the number of invasive species in the sub-locations.

Further probing of KIs was done to establish the duration for which the species have been considered invasive in the area. The results show that the longest duration the species have been invasive was 46 and 45 years for *Vachelia reficiens* and *Justicia striata* respectively, while the shortest duration the species can be said to have been invasive was 2-5 years and this is for the exotic species mainly introduced recently for various uses e.g., fencing. *Vachelia reficiens* and *Prosopis juliflora* which are the species of concern to the study were noted to be invasive for the last 46 and 20 years respectively. This showed that the duration since the species were identified in the

area was over 20 years implying that any form of impact both to the Socio-economic activities and to the environment is clearly known among the residents.

4.3 Impacts of the *Vachelia reficiens* and *Prosopis juliflora* on Socio-Economic Activities

Impacts of the two species on social and economic aspects of the local populace are described in sub-section 4.3.1 to 4.3.2.

4.3.1 Socio-economic impacts of *Vachelia reficiens*

The study established the impact and magnitude of *Vachelia reficiens* on socio-economic activities of the residents in each of the sub-locations sampled for the study. The results are presented in Table 4.7.

Table 4.7. Impacts and Magnitude of *Vachelia reficiens* on Socio-Economic Aspects of the Households

	Frequency of Magnitude of Impacts (%), (N=122)						
Socio-Economic Attributes	**No Impacts**	**Insignificant**	**Minor**	**Moderate**	**Major**	**Severe**	**Totals (%)**
Governance	0	0.8	10.7	41	42	5.7	100
Livestock Production	0	0	2.5	27.8	53.3	16.4	100
Income & Expenditure	0	8.2	34.4	39.4	15.8	2.4	100
Local Transport	0	0	12.0	43	34	11	100
Natural Resource Use Conflicts	0	6.0	34	34	16	10	100
Average	**0**	**3**	**18.7**	**37.04**	**32.22**	**9.1**	

The results in Table 4.7 shows that *Vachelia reficiens* had an impact on the socio-economic activities of the residents in all the sub-locations. On governance impacts

in terms of grazing systems and rules, 42% indicated *Vachelia reficiens* impacted majorly, 41% indicated that the species had a moderate impact. This implies that Vachelia *reficiens* had made it more difficult for the communities to observe the grazing systems and rules as the plants affects the management of the grazing areas and water points. This could be attributed to the plant'ssuppression of other plants, blocking and depleting water sources. This supports the findings of (Terefe et al., 2011; Ouko et al., 2020), on woody invasive plants impacting on the socio-economic activities of the households.

Livestock production in terms of yields, health, diseases, injuries and trapping were also impacted by the species. The results show that *Vachelia reficiens* also had an impact in most of the areas. It is however, noted that *Vachelia reficiens* again has a major impact on livestock production as 53.3% respondents indicated it had a major impact, while 27.8% indicated that the plant had moderate impact , 16.4% indicated that it had severe impact on the livestock production. This implies that in most of the areas the severity of the impact of *Vachelia reficiens* can be seen in terms of the lowered livestock productivity and increased diseases caused by red ear tick harboured by the plant. The plant is reported also to decrease livestock herds and increase livestock movements due to decreased availability of grass hence reduced productivity. This also supports the findings of Farag et al. (2018) who also noted that invasive species have an effect on the households' economy.

The results also show that *Vachelia reficiens* had varying degrees of impact on the Income and expenditure of household. The results showed that *Vachelia reficiens* had greater impact in some areas than others, 39.4% indicated that the plant had moderate impact on their income and expenditures while 34.4% indicated minor impact on the income and expenditure of the residents. While 15.8 % indicated a major impact of

the species on the income and expenditure sources of the households. This implies that this invasive species has an impact on the income and expenditure of the household.

On local transport and access to various services-, 34% of the respondents indicated *Vachelia reficiens* had a major impact on the local transport services because of its nature of spreading very fast and forming impenetrable thickets. This was followed by 43% of the respondents who indicated that *Vachelia reficiens* had moderate impact, while 11 % indicated that it had severe impact on the transport systems and access to various services in the area and 12.0% indicated a minor impact on the local transport. This was attributed to the fact that the plant grows in closely spaced stands, is multi-stemmed, and has large branches and spines thus creating thickets that are hard to move through. It has further made rerouting of existing paths and routes. The thickets were reported to attract predators as the plant thickets traps livestock making it difficult for residents to rescue trapped livestock hence more predation by wildlife.

On natural resource use conflicts in the area, 34% of the respondents indicated the species impacts as minor, 34% indicated moderate impacts, 16% indicated that the impact was major and only 10 % indicated that the impact was severe. This implies that the invasive species has a characteristic of blocking other species from growing because of its thick canopy hence depleting resources such as water and grass and limiting access to many users. Its tendency to block pathways and corridors has led to serious conflicts between human activities and wildlife. This implies that the prevalence of the species in most of the areas affects the natural use of resources and this leads to conflicts and disputes among the residents and wildlife.

The results further were assessed to determine the mean impacts of the species on various Socio-economic attributes of the households in the sub-county. The results are presented in Table 4.8.

Table 4.8: **Mean Impacts of *Vachelia reficiens* on Socio-Economic Activities**

Socio-economic Activity Impacted	Mean
Governance	3.58
Livestock production	3.36
Income and expenditure	3.54
Local transport	3.85
Natural resource use conflicts	2.41
Average	3.4

Source: Author, 2023)

Comparison of the means indicate that *Vachelia reficiens* has had major impacts on local transport, income and expenditure and governance while it had moderate impacts on livestock production and minor impacts on natural resource use conflicts. On average *Vachelia reficiens* had moderate impacts on socio-economic systems of the residents in the study area.

4.3.2 Socio-economic impacts of *Prosopis juliflora*

In order to assess the impact of *Prosopis juliflora* on the socio-economic activities of the households the results were analyzed and presented in Table 4.9.

Table 4.9: Impacts and Magnitude of *Prosopis juliflora* on Socio-Economic Activities of the Households

	Frequency of Magnitude of Impacts (%), (N=122)						
Economic Activity	**No Impacts**	**Insignificant**	**Minor**	**Moderate**	**Major**	**Severe**	**Totals (%)**
Governance	16	46	25	8.2	4	0.8	100
Livestock Production	16	12	31.9	25	11	4.1	100
Income & Expenditure	16	36.1	32	13.9	2	0	100
Local Transport	16	13	39	18.7	10	3.3	100
Natural Resource Use Conflicts	16	46.7	23.7	13	0.8	0	100
Average	**16**	**30.8**	**30.3**	**15.8**	**5.6**	**1.6**	

The results in Table 4.9 shows that *Prosopis juliflora,* has an impact on the Socio-economic activities of the residents in most of the sub-locations. However, most of the respondents indicated that it has insignificant impacts. Regarding the impact on the governance in terms of grazing systems and rules, 46% of the respondents indicated the species to have insignificant impacts, 25% indicated the species posed minor impacts on the governance of grazing systems and rules. Only 8.2% said it had moderate impact compared to 4% who said it had major impact. This implies that this species does not have a significant impact on the socio-economic activities of the households despite of its existence in most parts of the sub-county and hence the impact is still low and impacts are site specific depending on the scale of infestation.

On species impacts on livestock production, it is noted that most 31.9% of the respondents indicated that *Prosopis juliflora* had a minor impact followed by a similar response 25% who indicated that it had a moderate impact, 11% indicated that the species had major impact while 4.1% indicated it had a severe impact. 12% indicated it had insignificant impacts. This implies that in most of the areas *Prosopis juliflora* species is fast spreading and hence becoming a major concern by the residents and hence their infestation rate is of concern regarding the impact on livestock production in the three divisions thus requiring monitoring. The dense thickets tend to be perfect hiding places for predators and this increases the risk of losing the livestock to the predators. The thickets also provide breeding places for the pests and this causes increased incidents of pests and diseases. The species was not present in at least 16% of the areas covered by the study.

The results also show that *Prosopis juliflora* had varying degrees of impact on the Income and expenditure sources of the residents, diversity and household costs. Most of the respondents 36.1% indicated that the species has an insignificant impact on the income and expenditure of the households, 32% indicated minor impacts, and 13.9% indicated that it has moderate impact, while only 2 % indicated that the plant has major impact. This shows that in most of the sub-locations, the households indicated that *Prosopis juliflora* has insignificant impact on the income and expenditure at the household level. This could be attributed to the fact that the species was introduced recently. However, it is causing an impact on the household income and expenditure as it is directly affecting the sources of income for the households. The species is reported to injure livestock and causes bruises and wounds in their bodies necessitating use of drugs in treatment and further reduces livestock body condition and products thus decreased income and increase in expenditure.

On species impacts on local transport and access to various services, the results show that 13% indicated insignificant impacts, majority of the respondents 39% indicated that *Prosopis juliflora* has minor impact while 18.7% indicated that it has moderate impact, 10% indicated that it has a major impact in the area, while only 3.3% indicated a severe impact. This is attributed to the fact that the species is commonly seen growing along the roads and at watering areas. The species grows and spreads out very fast and hence it blocks the designated routes and covers the watering areas for the animals and the households making it difficult for the people to access this areas. The results also show that at least 16% of the study area did not have the species as it had not been introduced and hence there was nothing perceived about the impact within the sub-location.

Regarding the impact of *Prosopis juliflora* on the natural resource use conflicts/disputes, the results show that *Prosopis juliflora* also had varying impacts on the use of natural resources and conflicts in the area. The results show that most of the respondents 46.7% and 23.7% indicated that the species had insignificant impact and minor impacts respectively. It was also noted that 13% of the species had moderate impact while 0.8 % of the respondents indicated a major impact on the natural resource use conflicts among the households. This again implies that although *Prosopis juliflora* is seen to pose a threat to the natural resource, leading to increase in conflicts and disputes between communities, households and human wild life conflict, the impact is not yet major in most parts of the study area.

The results further were assessed to determine the mean impacts of the species on various Socio-economic attributes among households. The results are presented in Table 4.10.

Table 4.10: Mean Impact of *Prosopis juliflora* on Socio-Economic Activities

Socio-economic activities Impacted	Mean
Governance	2.81
Livestock production	2.52
Income and expenditure	1.45
Local transport	2.21
Natural resource use conflicts	1.63
Average	**2.1**

Source: (Author, 2023)

On comparison of the means of impacts on socio-economic activities of the residents, *Prosopis juliflora* had moderate impacts on governance and livestock production while minor impacts on income and expenditure, natural resource use conflicts and local transport. On average it scored minor impacts on socio-economic activities.

4..4 *Vachelia reficiens* and *Prosopis juliflora* paired mean impacts magnitude on socio-economic attributes

The study further sought to assess whether there were any significance differences between the impacts of the two species on the Socio-economic activities of the households. This was done using the paired means and the results were presented in Figure 4.7.

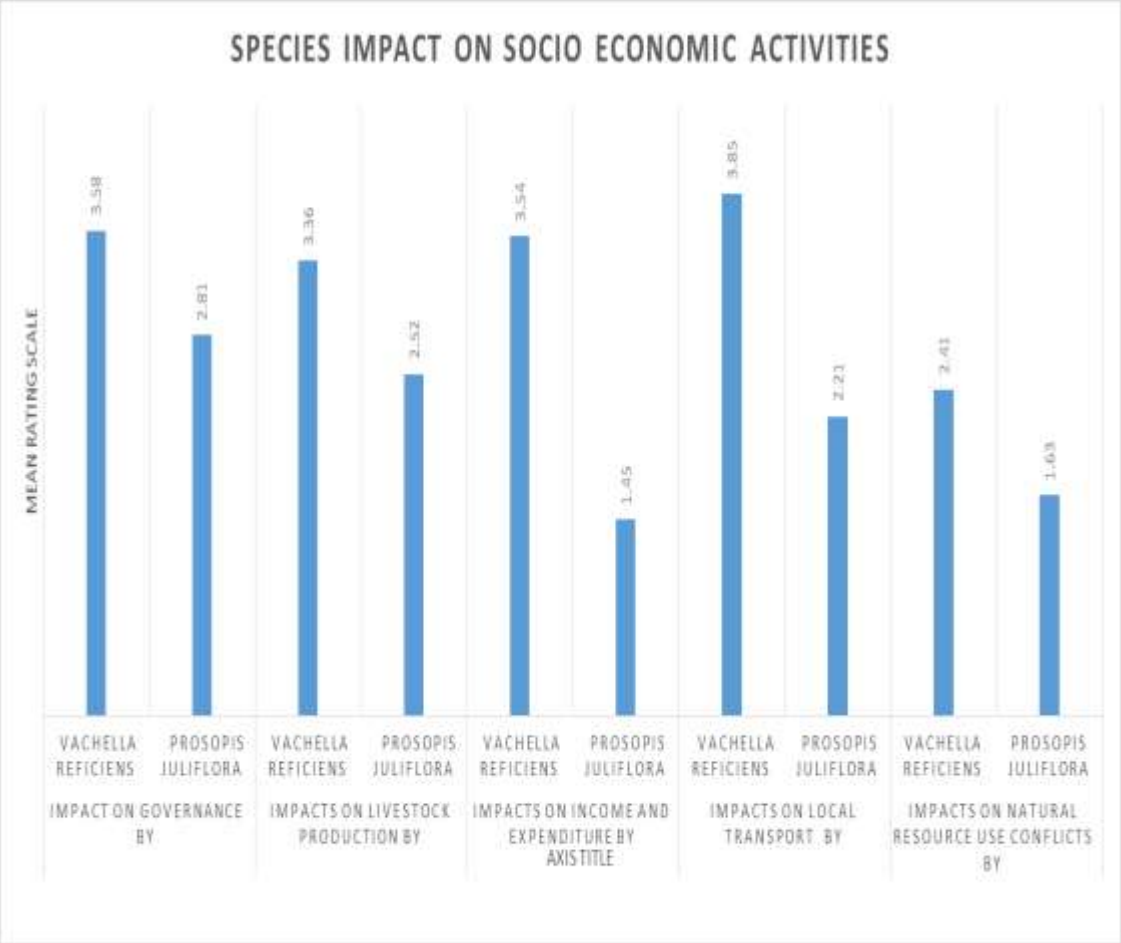

Figure 4.7: *Species mean impacts magnitude on socio-economic activities*

The results in Figure 4.7 shows that there were differences between the mean impact of *Vachelia reficiens* and *Prosopis juliflora* species on the socio- economic activities in the study area. On average *Vachelia reficiens* scored moderate to major impacts while *Prosopis juliflora* scored minor to moderate impacts. This could be attributed to the characteristics of the specie and its history of long existence.

4.5 Paired statistics on species mean impacts on socio-economic activities

Sub-section 4.5.1 and 4.5.2 describes paired means of the impacts of the two species on socio-economic activities.

4.5.1 Paired sample statistics of species impacts on socio-economic attributes

The sample means of the responses between *vachelia reficiens* and the mean of *prosopis juliflora* on the socio- economic activities. The results are presented in Table 4.11.

Table 4.11: Paired Samples Statistics on the Impact of Species on Socio - Economic Activities

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Impacts of *Vachelia reficiens* on governance	3.58	122	.811	.073
	Impacts of *Prosopis juliflora* on governance	2.81	122	1.363	.123
Pair 2	Impacts of *Vachelia reficiens* on livestock production	3.36	122	.873	.079
	Impacts of *Prosopis juliflora* on livestock production	2.52	122	1.274	.115
Pair 3	Impacts of *Vachelia reficiens* on income and expenditure	3.54	122	1.107	.100
	Impacts of *Prosopis juliflora* on income and expenditure	1.45	122	.919	.083
Pair 4	Impacts of *Vachelia reficiens* on local transport	3.85	122	1.162	.105
	Impacts of *Prosopis juliflora* On local transport	2.21	122	1.235	.112
Pair 5	Impacts of *Vachelia reficiens* on natural resource use conflicts	2.41	122	.977	.088
	Impacts of *Prosopis juliflora* on natural resource use conflicts on	1.63	122	.911	.082

The results in Table 4.11 shows that *Vachelia reficiens* had high mean impact on all

the five socio-economic aspects compared to *Prosopis juliflora*. This shows that *Vachelia reficiens* is more harmful to socio-economic activities of the residents compared with Prosopis juliflora. This important in the prioritization of resources and interventions for the species beginning with *Vachelia reficiens*.

4.5.2 Paired t test of species impacts on socio-economic attributes

The study sought to establish the statistical differences in the means of the responses between *vachelia reficiens* and the mean of *prosopis juliflora* on the socio- economic activities. The results are presented in Table 4.12.

Table 4.12: Paired t Tests of Species Impact on Socio- Economic Activities

Activities		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	Impacts of *Vachelia reficiens* on governance Impacts of *Prosopis juliflora* on governance	.770	1.465	.133	5.810	121	.000
Pair 2	Impacts of *Vachelia reficiens* on livestock production Impacts of *Prosopis juliflora* On livestock production	.836	1.351	.122	6.837	121	.000
Pair 3	Impacts of *Vachelia reficiens* on income and expenditure Impacts of *Prosopis juliflora* on income and expenditure	2.090	1.420	.129	16.257	121	.000
Pair 4	Impacts of *Vachelia reficiens* on local transport Impacts of *Prosopis juliflora* on local transport	1.639	1.642	.149	11.029	121	.000
Pair 5	Impacts of *Vachelia reficiens* On natural resource use conflicts Impacts of *Prosopis juliflora* on natural resource use conflicts	.779	1.283	.116	6.706	121	.000

The results in Table 4.12 shows that there was a statistical significance difference

between the mean impacts of the species on the various Socio-economic activities of the households as shown by a *p* value <0.05 for socio-economic activities. The results also show that both species have a statistically significant mean difference on their impact on Socio-economic activities. In all the socio-economic activities it is noted that the mean difference between the two species is statistically significant on all the five aspects under consideration. The results revealed that the mean impacts of *Vachelia reficiens* and *Prosopis juliflora* on the Socio-economic systems of among households is statistically different with *Vachelia reficiens* seemingly having a higher level of impact on the households Socio-economic activities than *Prosopis juliflora.* This is attributed to the level of spread of the two species and also the level of management interventions directed to the species.

4.6 Qualitative analysis of the impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio-economic attributes

The results from the household respondents, Key Informants and the Focus Group Discussion were also discussed, where common themes and narratives in the questionnaires and guides were identified and presented in their actual and discussed as follows;

The respondents indicated that to a great extent the species affected governance, livestock production, income and expenditure and local transport. The results revealed that majority of the respondents indicated that they were aware of the existence of the species.

On the impacts, majority of the respondents indicated that the species have weakened and disrupted the originally strong and effective grazing systems which has led to a total collapse of traditional governance systems and structures e.g., Grazing

committees, council of elders, dry and wet-season grazing systems. The evaluation also indicated that livestock production has been affected by *Vachelia reficiens* as the species has a tendency of overtaking grasslands hence leading to poor fodder in most areas hence forcing displacement of communities and their livestock thus affecting their production. The results further show that grazing systems/pattern have been changed due to increased cover of *Prosopis juliflora* which has taken over Ewaso Ngiro river glades which have always served as the traditional grazing areas for livestock during the dry season grazing.

Most of the participants indicated that there has been livestock herd size reduction due to depleted grasses and forage. They also noted that the presence of the species has contributed to a great extent to the instability of livestock production. Respondents indicated that there has been increased livestock mobility and migration to far areas in search of grass and water. This leads to high level of loss and reduced production among the livestock. It was further noted that the species have highly affected the livestock health hence production due to frequent migration for pasture and water occasioned by declining grass capacity of range lands.

The impact of the species presence has also contributed to increased natural resource use conflicts in areas migrated to (Marsabit, Isiolo, Baringo, Laikipia, Nyandarua and Nyeri Counties). The prevalence of the conflicts can be traced since 2009 when the impact of the species was evident in most of the areas. The impact of the species can also be explained by the frequency of armed conflicts and the human-wildlife conflicts due to high livestock mobility on migrations to other counties.

The displacement of the ecosystem has greatly affected natural foods such as wild fruits particularly derived from Grewia and Cordia species. The production of honey

which is a source of income as an economic activity in the dry regions. The honey plants have greatly been displaced by the *Vachelia reficiens* and *Prosopis juliflora* species. The invasive plants have increased poverty and malnutrition as main livestock products like milk are no longer available. Displacement of wildlife and vegetation has led to reduced potential for ecotourism hence reduced income from tourism as tourism circuit is distorted.

The analysis further noted that income and expenditure due to plant risks, *Prosopis juliflora* thorns are injurious and cancerous to human and livestock and substantial income has been directed to meet medical costs including transportation. Further they harbour mosquitoes. Quality of livestock products has been reduced by the effects of *Prosopis juliflora*. The plant tends to lower the value of animal skin and hides as thorns cause injury and swelling hence reduction in market prices. This is also contributed by the low productivity of the land due to loss of soil fertility and increased soil erosion and abundance of gullies.

In regard to transport and accessibility for both human and livestock *Vachelia reficiens* and P*rosopis juliflora* thickets have blocked river banks and resource access routes causing rerouting of them to access goods and services. The *Prosopis juliflora* thickets have really affected the accessibility of human, livestock and wild animals to their destinations giving rise to human-wildlife conflicts.

This implied that *Vachelia reficiens* had an impact on the socio-economic attributes of households in Samburu East Sub-County. The results further agreed with the findings of Wambua et al. (2020) and Kairu et al. (2010) who noted that invasive plants lower grass production by reducing the capacity of grasslands to support grass thus reducing food availability to grazers. Similarly, Obiri (2011) found that the invasive plants

greatly impactedsocio-economic undertakings eventualy leading to prevalence of poverty among resident communities living in areas of infestations. This views were further supported by Bufebo et al. (2018) and Nackley et al. (2017) on species negative impacts to social and economic activities of residents.

4.7 Analysis of Variance of species impacts on socio-economic activities

Further analysis was done to assess whether the species impacts are statistically different. This was done using the Analysis of variance (ANOVA). This is presented in Table 4.13.

Table 4.13 : Analysis of Variance for Impact of *Vachelia reficiens* and Prosopis juliflora on Socio- Economic Activities

Vachelia reficiens	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	22.972	17	1.351	2.478	.003
Within Groups	56.709	104	.545		
Total	79.680	121			
Prosopis juliflora					
Between Groups	24.796	19	1.305	2.425	.002
Within Groups	54.884	102	.538		
Total	79.680	121			

The results show that the mean difference of the impacts of *Vachelia reficiens* is of statistical significance as shown by the F statistic of 2.478 and a p value of 0.003 f while for *Prosopis juliflora* the F statistic is 2.425 and the p value of 0.002. This implies that the mean impact between the two species on socioeconomic activities in the three divisions was statistically significant.

4.8 Impacts of *Vachelia reficiens* and *Prosopis juliflora* on Selected Components of Environment

Impacts of the two species on environmental components of the sub-locations are described in sub-section 4.7.1 to 4.7.2.

4.8.1 Environmental impacts of *Vachelia reficiens*

This section presents the findings on the impacts of *Vachelia reficiens* on environmental components in the sub-locations. The results are presented in Table 4.14.

Table 4.14: Impacts and Magnitude of *Vachelia reficiens* on Environmental Components

Environment Component	Frequency of Magnitude of Impacts (%), (N=122)						
	No Impacts	**Insignificant**	**Minor**	**Moderate**	**Major**	**Severe**	**Totals (%)**
Water Availability	0	2.5	16.4	52.5	21.3	7.4	100
Wildlife	0	0	13.1	41	38	7.4	100
Land Productivity	0	7.4	8.2	41.8	31.2	11.5	100
Grassland	0	0	4.9	30.3	43.5	21.3	100
Natural Regeneration	0	6	1.6	8.2	48.4	41.8	100
Average	**0**	**3.2**	**8.8**	**34.8**	**36.5**	**17.9**	100

The findings in Table 4.14 shows that the impact of *Vachelia reficiens* on water availability in the area was moderate as shown by 52.5% of the responses followed by 21.3% who indicated that it was major, while 16.4 % said it was minor, 7.4% said the impact was severe. This implies that *Vachelia reficiens* had a significant impact on the water availability in the study area. The plant has the tendency of draining off the

little available water from the surface and this makes it difficult for the other fodder plants to grow. This was attributed to its fibrous and deep rooting system.

In regard to the impact of the species on wildlife, the results show that *Vachelia reficiens* was considered to have a high impact on the wildlife, 41% indicated that the species had a moderate impact, 38.0 % indicated that it had a major impact, 13.1% indicated a minor impact while 7.4% indicated severe impact of the species on the wildlife. This could be as a result of the plants forming thickets which are used by predators as hiding grounds and they also harbour pests such as ticks which affect the movement and health of wildlife. The plant also has attributes which suppresses the growth of other plants including grass thus affects the growth and development of the grass and other fodder used by herbivores as food. This has caused migration of wildlife to areas where these resources are found leading to serious wildlife imbalance in the area.

On *Vachelia reficiens* impacts on the land productivity, 41.8% of the respondents indicated Vachelia *reficiens* had a moderate effect, 31.2% indicated that it had a major impact while 11.5% indicated that it had severe impact on the land productivity in their area. 8.2 indicated minor impacts while 7.4 indicated insignificant impacts on land productivity. This implies that *Vachelia reficiens had a* greater impact on the land productivity hence there is need to enhance the control mechanism for the *Vachelia reficiens* in most of the areas as it affected land productivity in most of the areas hence affecting the environmental quality. This was more so because it aggravates loss of soil cover in terms of plants leading to soil erosion.

The study examined whether *Vachelia reficiens* impacted on the grassland in the sub locations. The results revealed, that 43.5% of the respondents indicated that *Vachelia*

reficiens had major impacts, 30.3 % indicated moderate impact on the grasslands, 21.3% indicated that it had a severe impact, only 4.9% indicated that it had minor impact on the grassland in their areas. The results again show that *Vachelia reficiens* had a greater impact on the grasslands hence indicating that it had a higher impact on the environmental systems. This was because the plants suppresses growth of grass and eventually colonize areas of grasslands.

The study further assessed whether *Vachelia reficiens* impacted on the natural regeneration. The results revealed that 48.4% of the respondents indicated that *Vachelia reficiens* had major impact, 41.8% indicated that it had a severe impact on the grasslands, 8.2% indicated that it had minor impact, only 6% indicated that it had insignificant impact on the natural regeneration in their areas. The results further show that *Vachelia reficiens* had a greater impact on the natural regeneration hence indicating that it had a higher impact on the biodiversity in the sub-locations. The results further were assessed to determine the mean impacts of the species on various environmental aspects in the sub-county. The results were presented on Table 4.15.

Table 4.15: Mean Impacts of *Vachelia reficiens* on Environmental Components

Environmental Components Impacted	Mean
Water availability	3.12
Wildlife	3.43
land productivity	3.43
Grasslands	4.16
Natural regeneration	4.47
Mean	**3.72**

Source: Author (2023)

Comparison of the means indicate that *Vachelia reficiens* had severe impacts on natural regeneration, major impact on grasslands and moderate impacts on water availability, wildlife and land productivity. On average *Vachelia reficiens* had major impacts on environmental components in Samburu East Sub-County.

Because of the impacts it had on natural regeneration and wildlife, it was important for the study to establish the knowledge of the households on the plants and wildlife which have been displaced by the invasive species in the sub-county the results are presented in Table 4.16 (a, b, c).

Table 4.16 (a): Multipurpose Indigenous Plants Displaced to Local Extinction by *Vachelia reficiens*

Trees/Shrubs	Growth Form	Local Name (Samburu)	Importance	Frequency	%
Vachelia tortilis (Forssk) Hayne.	T	Ltepes	Fodder	16	15.8
Senegalia melifera (M. vahl) Benth.	S	Iti	Bee forage	15	14.9
Cordia quercifolia Klotzsch.	S	Silapani	Ceremonial/ wild fruits	5	5.0
Cordia sinensis Lam.	S	Lgweita	Wild fruits	10	9.9
Salvadora persica L.	S	Sekotei	Medicinal		
Grewia tenax (Forssk.) Fiori	S	Lpusan	Wild fruits	7	6.9
Grewia bicolor Juss	S	Laitipai	Wild fruits	4	4.0
Lannea schimperi (Hochst)	S	Lampurori	Rope making	2	2.0
Vatovaea pseudolablab (Hamms)	Climber	Njasi	Sweet tubers	2	2.0
Vachelia etbaica (Schweinf.) Kyal & Boatwr	T	Ljakwai	Bee forage	1	1.0
Senegalia senegal (L.) Britton.	S	Lderkesi	Gums, bee forage	2	2.0
Commelina Africana L.	H	Naiteteyai	Forage	9	8.9
Indigofera spinosa Forssk.	H	Lkitangesi	Forage	6	5.9
Aspila mossambicensis (Oliv.)	H	Loiyapasei	Forage	10	9.9
Blepharis linariifolia Pers.	H	Lmarag	Forage	12	11.9
Total				**101**	

T-Tree **S**-Shrub **H**-Herb

Source: Author (2023)

Table 4.16 (b): High Value Grass Species Displaced to Local Extinction by *Vachelia reficiens*

Grass	Local Name (Samburu)	Frequency	%
Chrysopogon plumulosus Hochst	Lkawa	51	31 0
Leptothrium senegalense (Kunth)	Loonoro	29	18.0
Pennisetum mezianum Leeke	Lkurme	25	15.0
Pennisetum stranineum Peter	Ntalagwani	8	5.0
Digitaria velutina (Forssk)	Lanana	41	25.0
Tetrapogon cencriformis (A.Rich) Clayton.	Lterian	4	2.0
*Panicum deustum*Thunb	Laraa	5	3.0
Andropogon gayanus kunth	Larau	1	1.0
Digitaria macroblephara (Hack. Ex Schinz) Paoli	Loiroturoto	1	1.0
		165	

Source: Omollo et al. (2023), Author (2023).

The results show that the plants that had been displaced most were the grasses as shown by 31% who indicated that the grass type *Chrysopogon plumulosus* has been displaced followed by *Digitaria velutina* which was noted by 25% of the respondents as having been displaced by the invasive species. Among the shrubs *Vachelia tortilis* and *Vachelia melifera* were known to have been displaced to the point of extinction in the sub-county as noted by 15.8% and 14.9% respectively. While *Blepharis linariifolia* was also considered to be near extinction as 11.9% of the respondents noted. This shows that the invasive plants have had a great impact on the shrubs and grasses which have been considered to be near to extinction in the sub-county.

It was also important to consider the knowledge of the households members on the wild life that have been displaced in the sub-county by the invasive plants as shown in Table 4.16 (c).

Table 4.16 (c): Wildlife Displaced by *Vachelia reficiens*

Wildlife	Frequency	Percentage
Antelopes	14	9.5
Grant gazelle	8	5.4
Buffaloes	17	11.6
Elephants	13	8.8
Thompson gazelles	18	12.2
Gerenuk	2	1.4
Impala	2	1.4
Lesser kudu	1	0.7
Greater kudu	6	4.1
Warthog	1	0.7
Rhino	8	5.4
Eland	10	6.8
Oryx	5	3.4
Giraffe	8	5.4
Zebra	34	23.1

Source: Author (2023)

The results show that the most affected animal species are the zebras (23.1%), followed by Thompson gazelles (12.2%) and Buffaloes (11.6%). This shows that the invasive plants have had an impact on the animal species too as they have affected the food chain and displaced the plants which are their main food. This agrees with the findings of Ouko *et al*. (2020) who found that invasive plant species threatens Kenya's biodiversity and Ng'weno *et al*. (2010) who reported that invasive plants distort food chains, lower grass production by reducing available food to grazers. The invasive plants have also blocked the escape routes for these small animals making it easier for the predators to prey on them. This explains further the wildlife imbalance

as more predators are reported to exist in the area as herbivores have migrated to other areas in search of pastures. The impact of *Vachelia reficiens* by causing species local extinctions agrees with the findings of Howard et al. (2019) and Bellard et al. (2018) on species extinctions as a result of invasion by invasive species.

4.8.2 Environmental impacts of *Prosopis juliflora*

The study further sought to explicate the impact of *Prosopis juliflora* on the environmental components in the sub-locations. The output of data were analyzed and presented in Table 4.17.

Table 4.17: Impacts and Magnitude of *Prosopis juliflora* on Environmental Components

	Frequency ofMagnitude of Impacts (%), (N=122)						
Environmental Component	**No Impacts**	**Insignificant**	**Minor**	**Moderate**	**Major**	**Severe**	**Totals (%)**
Water Availability	15.6	7.4	46.7	15.6	9.8	4.9	100
Wildlife	15.6	13	42	15.6	13.9	0	100
Land productivity	14.8	16.4	42.7	15.6	6.6	4.1	100
Grasslands	16.4	24.6	34.4	12.3	9.8	2.5	100
Natural Regeneration	15	0.8	23	39	17.2	5	100
Average	**15.5**	**12.4**	**37.8**	**19.6**	**11.5**	**3.3**	

The results in Table 4.17 shows the impact of *Prosopis juliflora* on environmental components vary. The results showed that most of the respondents 46.5% indicated that the impact of the species on the water availability was minor, 15.6% indicated that it had moderate impact, while 9.8% indicated that it had major impact, 15.6% indicated it had no impact and only 4.9 % indicated a severe impact on water availability. This could be attributed to the fact that this species are commonly found around the water catchment areas and when they infest the areas they multiply very fast and draw out the little available water leading to drying of the rivers, water pans and other water sources.

In regard to the impact of the species on wildlife, the results show that 42% of the respondents indicated that the impact of the plant was minor, 13% indicated insignificant impacts, and 15.6% indicated that it had moderate impact on wildlife, while 13.9% indicated that it had a major impact on wild life. The results further revealed that only 15.6% indicated that the species had no impact on the wildlife. This implies that *Prosopis juliflora* had minor impact on the wildlife. The impacts were attributed to the fact that the species is not good for animal fodder yet it grows to replace the fodder and grasslands for the wild animals. The plant also cause diseases as it is a breeding places for the pests and disease-causing pests in animals. The plant cause bloat among animals when they are eaten by mistake.

On *Prosopis juli*flora impacts on the land productivity, 42.7% of the respondents indicated the species posed minor impacts on land productivity, 16.4% said that it had insignificant impact, 15.6 % said it had moderate impact on land productivity, 6.6% indicated that it had major impact on land productivity while 4.1% indicated severe impacts. This was because the plant was reported to suppress undergrowth of any plant thus leaving the soil bare and vulnerable to soil erosion.

The study assessed whether Prosopis *juliflora* posed impacts on the grassland in the sub-locations. The results revealed that 34.4% of the respondents felt that the species had a minor impact on the grasslands, 24.6% indicated that it had an insignificant impact, 12.3% indicated that it had moderate impact, while 9.8% indicated that the species had major impact on the grassland in their areas. Only 2.5% said it had a severe impact on the grassland. This implies that *Prosopis juli*flora has varying impacts on the grassland. This is as a result of the nature of the plant where by the plant tends to displace the natural vegetation including grass and colonize grasslands hence affecting the environment.

The study also examined whether the invasive plants *Prosopis juli*flora impacted on the natural regeneration, 39% of the respondents indicated that *Prosopis juli*flora had moderate impacts. Further, 23% of the respondents indicated *Prosopis juli*flora had minor impact on natural regeneration. The results further show that 17.2% of the respondents indicated that the species had major impact, 5% indicated a severe impact, and 15% indicated no impacts on the natural regeneration in Samburu East Sub-County. This implies that *Prosopis juliflora* had an impact on the environmental components. On average most of the respondents felt the species had a minor impact on the environmental factors.

The results further were assessed to determine the mean impacts of the species on various environmental aspects in the sub-county. The results were presented in Table 4.18.

Table 4.18: Mean Impacts of *Prosopis juliflora* on Environmental Components

Environmental Component Impacted	Mean
Water availability	2.58
Wildlife	2.29
Land productivity	2.4
Grasslands	2.2
Natural regeneration	2.92
Mean	**2.5**

Source: Author (2023)

On comparison of the means, *Prosopis juliflora* had moderate impacts on natural regeneration and water availability while minor impacts on wildlife, land productivity and grasslands. On average it scored moderate impacts on environmental components.

Theeffects of *Prosopis juliflora* on the Flora and Fauna through displacement and local Extinction were analyzed. The results are presented in Table 4.19.

Table 4.19: Flora and Fauna Displaced to Local Extinction by *Prosopis juliflora*

Trees/shrubs	F	Grass	F	Forage	F	Fauna	F
Cordia sinensis	3	*Leptothrium senegalense*	2	*Commelina africana*	11	Water buck	2
Salvadora persica	3	*Chrysopogon plumulosus*	3			Warthog	1
Senegalia melifera	13	*Panicumm deustum*	1			Grant gazelle	1
Vachelia tortilis	9	Kaleis *species*	3			Impala	2
Grewia bicolor	3	*Pennnisetum mezianum*	4				

Source: Author (2023)

The results show that among the shrubs *Vachelia melifera* had the highest occurrence followed by *Vachelia tortilis*. Among the grasses *Pennnisetum mezianum* had the highest occurrence and among the forage *Commelina africana* had the highest occurrence on plants displaced to local extinction in areas infested by *Prosopis juliflora*. Water buck was the most affected wildlife species. This findings agrees with those of Shiferaw et al. (2021) and Nadio et al. (2020), on *Prosopis juliflora* reducing the availability of palatable grass in areas infested by the plant

4.9 *Vachelia reficiens* and *Prosopis juliflora* paired mean impacts magnitude on environmental components.

Analysis on species mean impacts on environmental components was done to determine species impacts in the sub-locations. The results are presented in Figure 4.8.

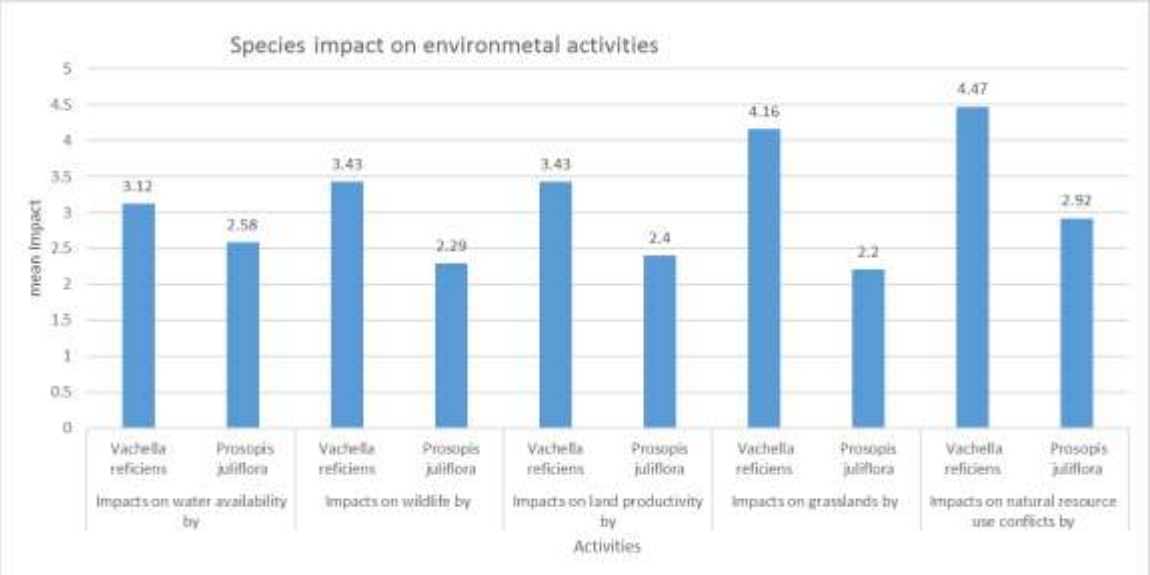

Figure 4.8: *Species mean impacts magnitude on environmental components*

The results in Figure 4.8 shows the impact of the species on environmental components vary. Most of the respondents indicated Vachelia *reficiens* to exhibit

higher impact on the environmental components among the sub-locations. The results showed that *Vachelia reficiens* had a higher impact with a mean of 3.72 while *Prosopis juliflora* had a mean impact of 2.5. This translates to *Vachelia reficiens* having had major impacts and *Prosopis juliflora* moderate impacts on environmental components in the sub-county.

4.10 Paired statistics of species mean impacts on environmental components

Sub-section 4.10.1 and 4.10.2 describes paired means of the impacts of the two species on environmental components.

4.10.1 Paired Samples Statistics on the Impact of Species on Environmental Components

The study sought to establish the differences in the sample means of the responses between V*achelia reficiens* and the mean of P*rosopis juliflora* on the environmental components. The results are presented in Table 4.20.

Table 4.20: Paired Samples Statistics on the Impact of Species on Environmental Components

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Impacts of *Vachelia reficiens* on water availability	3.12	122	.967	.088
	Impacts of *Prosopis juliflora* on water availability	2.58	122	1.090	.099
Pair 2	Impacts of *Vachelia reficiens* on wildlife	3.43	122	.832	.075
	Impacts of *Prosopis juliflora* on wildlife	2.29	122	1.168	.106
Pair 3	Impacts of on land productivity	3.43	122	1.076	.097
	Impacts of *Vachelia reficiens* on land productivity *Prosopis juliflora*	2.40	122	1.365	.124
Pair 4	Impacts of *Vachelia reficiens* on grasslands	4.16	122	.945	.086
	Impacts of *Prosopis juliflora* on grasslands	2.20	122	1.264	.114
Pair 5	Impacts of *Vachelia reficiens* on natural regeneration	4.47	122	.752	.068
	Impacts of *Prosopis juliflora* on natural regeneration	2.92	122	1.182	.107

The results in Table 4.20 show that *Vachelia reficiens* had high mean impact on all the five environmental components compared to *Prosopis juliflora*. This shows that *Vachelia reficiens* is more harmful to the environment of the sub-county.

4.10.2 Paired t test of species impacts on environmental components

The study sought to establish the statistical differences in the means of the responses between V*achelia reficiens* and the mean of P*rosopis juliflora* on the environmental components. The results are presented in Table 4.21.

Table 4.21: Paired t Tests of Species Impact on Environmental Components

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	Impacts of *Vachelia reficiens* on water availability Impacts of *Prosopis juliflora* on water availability	.541	1.247	.113	4.790	121	.000
Pair 2	Impacts of *Vachelia reficiens* on wildlife Impacts of *Prosopis juliflora* on wildlife	1.139	1.249	.113	10.079	121	.000
Pair 3	Impacts of *Vachelia reficiens* land productivity Impacts of *Prosopis juliflora* on land productivity	1.033	1.414	.128	8.069	121	.000
Pair 4	Impacts of *Vachelia reficiens* on grasslands Impacts of *Prosopis juliflora* on grasslands	1.959	1.534	.139	14.104	121	.000
Pair 5	Impacts of *Vachelia reficiens* on natural regeneration Impacts of *Prosopis juliflora* on natural regeneration	1.549	1.337	.121	12.801	121	.000

The results in Table 4.21 shows that the mean difference between the impacts of *Vachelia reficiens* and that of *Prosopis juliflora* are statistically significant in all the

environmental components. The results show that the impact is statistically significant as all the environmental components have shown a *p* value of less than 0.05.

4.11 Analysis of Variance on species impacts on environmental components

The analysis of variance was computed to assess the significance of the mean variance of the species. The results are presented in Table 4.22.

Table 4.22: Analysis of Variance for Impact of *Vachelia reficiens* and *Prosopis juliflora* on Environmental Components

Vachelia reficiens	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	18.614	13	1.432	2.532	.004
Within Groups	61.066	108	.565		
Total	79.680	121			
Prosopis juliflora					
Between Groups	28.225	21	1.344	2.612	.001
Within Groups	51.455	100	.515		
Total	79.680	121			

The results show that the variance between the *Vachelia reficiens* and the environmental components was statistically significant, though the value of the *F* statistic was low at 2.53 and the value of p of 0.004 which was lessr than 0.05. The results also show that there was a statistically significant variance between *prosopis juliflora* and environmental factors as shown by the F value = 2.612 and *P* value of 0.001 which is less than 0.05. This shows that the two species have a statistically significant impact on environmental components in the sub-county.

4.12 Qualitative analysis of species impacts on environmental components

The study further conducted analysis of households Questionnaires, Focus Group Discussions and Key Informants guides for key thematic perceptions.

On whether the species have had an impact on the water availability and quality in the area. The respondents indicated that the species do cause drying of water points contributing to water shortage. The plants tend to take up the little available water through their deep and fibrous roots hence leaving the area dry. *Prosopis juliflora* which grows mainly along the roads and the rivers and any other water catchment points has the characteristic of using up all the available water and leaving the place very dry. In terms of water quality, household heads indicated that massive soil erosion had increased the level of siltation in dams and water pans. Deep and fibrous root of the invasive plants tends to deplete underground water due to deep rooting system. This also makes it very difficult to eradicate these plants because of their deep rooting system. The leaves litter of these plants are acidic hence interferes with the water quality. Pollution of water as a result of low regulation on access and use has led to uncontrolled access and over use of the available water thus pollution of water sources has increased.

The respondents also indicated that the proliferation of these plant species in the area has led to wildlife imbalance as a result of distorted food chain. This implies that the plants have made it difficult for the ecosystem to effectively interact. There is no balance in the ecosystem as some of the animals have had to migrate leaving the area. The distortion of the ecosystem has increased the level of human-wildlife conflicts. This has resulted from the encroachment of the species which have reduced wildlife balance causing presence of more predators and migration of herbivores. At the same time the species have affected the grass land by rendering the range lands unproductive of the most palatable fodder for the herbivorous. The species do not offer any food solution to the wildlife in fact most of the respondents said that the

plants cause more harm to the animals as they act as hiding places for the predators, they harbour pests and insects which transmit diseases to the animals.

In regard to the local displacement/extinctions of flora and fauna, the summary made from the respondents indicated that majority of the respondents indicated that the species have a tendency to displace useful grass, forage, shrubs and trees important in the food chain in provision of ecosystem services and goods. This has led to total emigration of wildlife hence local extinction. The fear of many is that as the species tend to thrive in the dry areas and they displace the fodder and other grassland plants that are suitable for animal consumption, there is a likelihood of the species taking over the entire area and this will mean the livelihood of most household will be at stake. This will also lead to more livestock predation and death.

Respondents indicated that *Vachelia reficiens* has a tendency of increasing the temperatures in infested areas triggering warming of the environment. This makes the areas with larger cover of the species warmer than the rest of the areas. The reason behind this could be attributed to the poor ground cover which makes the bare soil not to absorb the heat and makes the place warmer. The bare ground also increases the chances of having erosion and this leads to the large gullies and also the soil surface is hardened suppressing the undergrowth of the other vegetation. This explains the reasons why the areas with large coverage of *Vachelia reficiens* have bare ground and have massive gulling due to soil erosion.

Prosopis juliflora species which is found mainly growing along the roads, settlements and in water catchment areas has led to increased loss of wetland ecosystems. The plant tend to block and choke off glades lead to displacement of key species like kaleis species. It isbelieved to have very deep andfibrous root system responsible for

increased water uptake thus increased water depletion in the area. The respondents indicated that the introduction of the species has made their livelihood more difficult and has heightened human wildlife conflicts, increased predators as the plant harmours predators which prey on the livestock. Affected households have lost the entire of camels and donkey herds rendering them poor as a result of mass livestock predation.

4.13 Spatial Variations of the Impacts of *Vachelia reficiens* and *Prosopis juliflora* Impacts

Understanding invasion spread patterns and underlying processes driving invasions are key to predicting and managing infestations. The study was interested in determining the time the species have been present in the area, spatial socio-economic and environmental impacts variations per division.

4.13.1 Spatial variations of socio-economic impacts of *Vachelia reficiens*

The spatial impacts of *Vachelia reficiens* on socio-economic activities of the residents in the sub-county have been analyzed. The results are presented inTable 4.23

Table 4.23. Spatial Variations on Socio-Economic Impacts of *Vachelia reficiens* in the Sub-County

Division	Year of Invasion	Economic Activity	Frequency of Magnitude of Impacts (%)							
Wamba (N=76)	1990		No Impact	Insignificant	Minor	Moderate	Major	Severe	Mode	Totals (%)
		Governance	0	0	5.3	52.6	35.5	6.6	3	100
		Livestock husbandry	0	0	1.32	30.27	59.21	9.21	4	100
		Income & Expenditure systems	2.6	2.6	39.5	31.6	19.7	4.0	2	100
		Transport services	0	0	6.6	57.9	28.9	6.6	3	100
		Natural Resource use Conflicts	0	1.3	31.6	39.5	21.1	6.5	3	100
	Impact Average		0.5	0.8	16.9	42.4	32.9	6.5	3	
Waso (N=21)	1990	Governance	0	0	9.5	38.1	42.9	9.5	4	100
		Livestock husbandry	0	0	0	19.0	61.9	19.0	4	100
		Income & Expenditure systems	0	0	38.1	42.9	19.0	0	3	100
		Transport services	0	0	4.8	33.3	52.4	9.5	4	100
		Natural Resource use Conflicts	0	9.5	19.0	23.8	19.0	28.7	5	100
	Impacts Average		0	1.9	14.3	31.4	39.0	13.4	4	
Sereolipi (N=25)	1980	Governance	0	4	32	8	56	0	4	100
		Livestock husbandry	0	0	8	28	24	40	5	100
		Income & Expenditure systems	0	32	4	60	4	0	3	100
		Transport services	0	0	36	4	32	28	2	100
		Natural Resource use Conflicts	0	16	52	20	4	8	2	100
	Impacts Average		0	10.4	26.4	24	24	15.2	3.2	

The results presented in Table 4.23 shows the spatial variations of the socio-economic impacts of *Vachelia reficiens* in the three divisions. The results show that in Wamba impacts were generally moderate to major on socio-economic activities but

moderate impacts on average. In Waso the results shows that the impact of invasion was moderate to major and major impacts in general. In Sereolipi the results show that the impact of *Vachelia reficiens* species was moderate to major but moderate in general. This implies that the impact of *Vachelia reficiens* was higher in Waso than in the other two divisions meaning that the socio-economic activities in Waso are highly affected by the invasion of the species.

In summary the results show that on spatial variations of socio-economic activities in the study area, *Vachelia reficiens* had on an average, moderate impacts in Wamba and Sereolipi divisions while it had major impacts in Waso division. This further can be attributed to the earlier introduction of the species from 'Talle' area in Isiolo County according to the respondents as reported elsewhere in this study.

4.13.2. Spatial variations of environmental impacts of *Vachelia reficiens*

The spatial variations of impacts of *Vachelia reficiens* on the environmental components was also assessed. Impacts on Various environmental components were considered and perceptions on variations of impacts among environmental components sought. The results are presented in Table 4.24.

Table 4.24: Spatial Variations of Environmental Impacts of *Vachelia reficiens* in the Sub-County

Division	Year of Invasion	Environmental impact	Frequency of Magnitude of Impacts (%)							
Wamba (N=76)	1990		No Impact	Insignificant	Minor	Moderate	Major	Severe	Mode	Totals (%)
		Water	0	0	6.6	65.8	18.4	9.2	3	100
		Wildlife	0	0	9.2	46.1	36.8	7.9	3	100
		Land Productivity	0	2.6	7.9	50	27.6	11.9	3	100
		Grasslands	0	0	2.6	40.8	43.4	13.2	3	100
		Natural Regeneration	0	0	1.3	6.6	57.9	34.2	4	100
	Impact Average		0	0.5	5.5	41.9	36.8	15.3	3.2	
Waso	1990	Water	0	4.8	19.0	52.4	14.3	9.5	3	100
(N=21)		Wildlife	0	0	9.5	23.8	47.6	19.1	4	100
		Land Productivity	0	0	9.5	42.9	23.8	23.8	3	100
		Grasslands	0	0	0	0	57.2	42.8	4	100
		Natural Regeneration	0	0	0	9.5	33.3	57.2	5	100
	Impacts Average		0	1	7.6	25.7	35.2	30.5	3.8	
Sereolipi (N=25)	1980	Water	0	8	32	24	36	0	4	100
		Wildlife	0	0	32	36	32	0	3	100
		Land Productivity	0	28	8	16	48	0	4	100
		Grasslands	0	0	16	24	32	28	4	100
		Natural Regeneration	0	0	4	8	32	56	5	100
	Impacts Average		0	7.2	18.4	21.6	36	16.8	3.8	

The results presented in Table 4.24 shows that on environmental components, *Vachelia reficiens* had on an average, moderate impacts in Wamba, major in Waso and Sereolipi divisions. The results shows that in Wamba impacts were generally moderate to major on environmental components but moderate impacts on average. In Waso and Sereolipi the results showed that the impact of invasion was moderate to major with major impacts in general. This implies that the impact of *Vachelia*

reficiens was higher in Waso and Sereolipi than in Wamba division meaning that the environmental components in Waso and Sereolipi were highly affected by the invasion of the species.

The results were further summarized to show the modal year of invasion of the species in each division, the average Socio-economic impact and the average environmental impact of the species. The responses are as shown in Table 4.25.

Table 4.25: Summary of the Spatial Variations of Impacts of *Vachelia reficiens* in the Sub-County

Division	*n*	Modal Year of Invasion	Average Socio-Economic Impacts	Average Environmental Impacts
Wamba	76	1990	3.2	3.8
Waso	21	1990	4.8	4.7
Sereolipi	25	1980	4.7	4.4
		Average	**4.2**	**4.3**

Source: (Author, 2023)

The results show that the impact of *Vachelia reficiens* on both socio-economic activities and environmental impact was major as shown by the mean values of 4.2 and 4.3 respectively. The plant has been perceived as invasive for 33 years in both Wamba and Waso and 43 years in Sereolipi divisions. Waso division being the most affected division followed closely by Sereolipi division.

4.13.3. Spatial variations of socio-economic impacts of *Prosopis juliflora*

The study also sought to find out the impact of *Prosopis juliflora* on the economic activities of the three divisions. The results showed that in Wamba the impacts were generally insignificant to minor on socio-economic activities but insignificant impacts on average. In Waso and Sereolipi the results show that the impact of invasion was

minor to moderate with minor impacts in general. Therefore, socioeconomic activities in Waso and Sereolipi were affected by the invasion of the specie. The results are presented in Table 4.26.

Table 4.26: Spatial Variations of Socio-Economic Impacts of *Prosopis juliflora* in the Sub-County

Division	Year of Invasion	Economic Activity	Frequency of Magnitude of Impacts (%)							
			No Impact	Insignificant	Minor	Moderate	Major	Severe	Mode	Totals (%)
Wamba (N=76)	1990	Governance	18.4	48.7	19.7	7.9	4.0	1.3	1	100
		Livestock Husbandry	18.4	17.1	40.8	18.4	5.3	0	2	100
		Income & Expenditure systems	19.7	50	18.4	11.9	0	0	1	100
		Transport srvices	18.4	22.4	32.9	19.7	2.6	4.0	2	100
		Natural Resource Conflicts	21.1	43.4	18.4	17.1	0	0	1	100
	Impact Average		19.2	36.3	26.0	15.0	2.4	1.1	1.4	
Waso		Governance	23.8	19	52.4	4.8	0	0	2	100
(N=21)		Livestock Husbandry	19	9.5	28.6	42.9	0	0	3	100
		Income & Expenditure systems	23.8	19	57.2	0	0	0	2	100
		Transport services	19.0	9.5	52.4	19.0	0	0	2	100
		Natural Resource Conflicts	19	23.8	52.4	4.8	0	0	2	100
	Impacts Average		20.9	16.2	48.6	14.3	0	0	2.2	
Sereolipi (N=25)		Governance	0	60	20	12	8	0	1	100
		Livestock Husbandry	0	0	16	24	40	20	4	100
		Income & Expenditure systems	0	4	52	32	12	0	2	100
		Transport services	0	0	32	12	40	16	4	100
		Natural Resource Conflicts	0	64	24	8	4	0	1	100
	Impacts Average		0	25.6	28.8	17.6	20.8	7.2	2.4	

The results presented in Table 4.26 shows that on socio-economic activities *Prosopis juliflora* had on an average, insignificant impacts in Wamba while minor in Waso and Sereolipi divisions. Sereolipi division being the most affected division in general. The presence of the species having been felt for 23 years in Wamba and Waso divisions and 33 years in Sereolipi division.

4.13.4 Spatial variations of environmental impacts of *Prosopis juliflora*

The study also sought to find out the spatial variations of environmental impacts of *prosopis juliflora*. The results show that in Wamba and Waso divisions the impacts were generally minor to moderate on environmental components but minor impacts on average. While in Sereolipi the results showed that the impacts of the specie was moderate to major with major impacts in general. This implies that the impacts of *Prosopis juliflora* were higher in Sereolipi division than in Wamba and Waso divisions meaning that the environmental components in Sereolipi were highly affected by the invasion of the specie. The results are presented in Table 4.27.

Table 4.27: Spatial Variations of Environmental Impacts of *Prosopis juliflora* in the Sub-County

Division	Year of Invasion	Economic Activity	Frequency of Magnitude of Impacts (%)							
			No Impact	Insignificant	Minor	Moderate	Major	Severe	Mode	Totals (%)
Wamba (N=76)	1990	Water	22.4	9.2	46.1	15.8	3.9	2.6	2	100
		Wildlife	21.1	22.4	34.2	17.1	5.3	0	2	100
		Land Productivity	18.4	19.7	38.2	10.5	6.6	6.6	2	100
		Grasslands	18.4	32.9	28.9	11.8	6.6	1.3	1	100
		Natural Regeneration	18.4	0	28.9	38.2	14.5	0	3	100
	Impact Average		19.7	16.8	35.3	18.7	7.5	2.0	2	
Waso (N=21)		Water	19.0	0	52.4	28.6	0	0	2	100
		Wildlife	66.7	0	14.3	19.0	0	0	0	100
		Land Productivity	19.0	14.3	57.1	9.5	0	0	2	100
		Grasslands	23.8	23.8	52.4	0	0	0	2	100
		Natural Regeneration	19.0	0	19.0	57.1	4.8	0	3	100
	Impacts Average		29.5	7.6	39.0	22.8	1	0	1.8	
Sereolipi (N=25)		Water	0	8	36	8	36	12	3	100
		Wildlife	0	0	40	8	52	0	4	100
		Land Productivity	0	8	40	40	12	0	2.5	100
		Grasslands	0	4	32	28	36	0	4	100
		Natural Regeneration	0	4	12	20	36	28	4	100
	Impacts Average		0	4.8	32	20.8	34.4	8	3.5	

The results presented in Table 4.27 shows that on environmental components *Prosopis juliflora* had on an average, minor impacts in both Wamba and Waso divisions and major in Sereolipi division. Sereolipi being the most affected divisions.

Table 4.28: Summary of the Spatial Variations of Impacts of *Prosopis juliflora* in the Sub-County

Administrative Division	Year of Invasion	Species Mean Impact Magnitude (Scale 0-5)	
		Socio-economic Impacts	Environmental Impacts
Wamba	2000	2.2	2.7
Waso	2000	3.3	2.8
Sereolipi	1990	3.8	4.0
Average		3.1	3.2

Source: (Author, 2023)

The results in Table 4.28 shows that the impact of *Prosopis juliflora* on both socio-economic activities and environmental impact was moderate as shown by the mean values of 3.1 and 3.2 respectively. The plant has been perceived as invasive for 23 years in both Wamba and Waso and 33 years in Sereolipi divisions. Sereolipi division being the most affected division followed by Waso division.

4.14 Paired t Test of Species Spatial Variations of Impacts

The study sought to establish whether there was a mean significant impact on the spatial variations between the two species. The paired t statistic and mean difference between the two species was computed and presented in Table 4.29.

Table 4.29: Paired t Test of Species Spatial Impacts in the Sub County

		Wamba	Mean difference	t	Sig.	Waso	Mean difference	t	Sig.	Sereolipi	Mean difference	t	Sig.
Pair 1	Socio-economic and *Vachelia reficiens*	3.2447	1.078	11.96	0.000	4.7524	1.495	17.43	0.000	4.6960	.944	8.593	0.000
	Socio-economic and *Prosopis juliflora*	2.1658			0.000	3.2571				3.7520			
Pair 2	Environmental and *Vachelia reficiens*	3.8105	1.103	12.17	0.000	4.7143	1.952	9.37	0.000	4.3680	.328	1.315	0.002
	Environmental and *Prosopis juliflora*	2.7079				2.7619				4.0400			

The results in Table 4.29 shows that the mean difference between the two species in terms of their impact on the spatial variation for Socio-economic activities was 1.078 in Wamba, 1.495 in Waso and 0.944 in Sereolipi. Regarding environmental components the results shows that both *Vachelia reficiens* and *Prosopis juliflora* had impacts on environmental components. The results showed that in Wamba the mean difference was 1.103, in Waso the difference was 1.952 and in Sereolipi the mean difference was 0.328. It is also noted that for all the three division the *t* statistic is statistically significant since all the p values are less than 0.05. This means that

impacts of the two species is significant in the divisions. This could be attributed to the year of invasion, the nature of the plant and also the interventions for management of the species. The results show that the mean impact was noted to be higher in Waso and Sereolipi in comparison with Wamba. This is because, interventions in the management of the species in were higher in Wamba than in Waso and absent in Sereolipi Division.

4.15 Analysis of Variance of Species Spatial Varaitions of Impacts in Divisions

The impacts of each species on socio-economic and environmental impacts in each division were also analyzed. The results of the analysis are presented in Table 4.30 (a, b, c).

Table 4.30 (a): Analysis of Variance of Species Socio-Economic and Environmental Impacts in Wamba Division

		Sum of Squares	df	Mean Square	F	Sig.
Socio - economic for *Vachelia reficiens*	Between Groups	23.146	5	4.629	16.582	.000
	Within Groups	19.542	70	.279		
	Total	42.688	75			
Environmental for *Vachelia reficiens*	Between Groups	6.316	5	1.263	4.269	.002
	Within Groups	20.715	70	.296		
	Total	27.032	75			
Socio- economic *Prosopis juliflora*	Between Groups	4.871	5	.974	2.037	.084
	Within Groups	33.480	70	.478		
	Total	38.351	75			
Environmental *Prosopis juliflora*	Between Groups	7.228	5	1.446	2.192	.065
	Within Groups	46.168	70	.660		
	Total	53.395	75			

The results in Table 4.30 (a) show that there is a statistically significant variance between the means of the responses in Wamba division regarding the impact variation of the *Vachelia reficiens* on both the socio- economic activities and environmental activities (F = 16.582.; P= 0.000, F = 4.269.; P= 0.002.) While for *Prosopis juliflora* the results have shown that there is no significant impact between the socio-economic activities and environmental components on spatial variation (F= 2.037.; p= 0.084, and F = 2.192.; p = 0.065) respectively. The test statistic was done at a significant level of 0.05, meaning that when the p value is less than 0.05, it indicated that there is a statistical significance difference between the spatial variations of *Vachelia reficiens* While for *Prosopis juliflora*, the results shown no statistical significance in variance between the two means.

Table 4.30 (b): Analysis of Variance of Species Socio-Economic and Environmental Impacts in Waso Division

		Sum of Squares	df	Mean Square	F	Sig.
Socio - economic for *Vachelia reficiens*	Between Groups	.392	4	.098	.934	.469
	Within Groups	1.680	16	.105		
	Total	2.072	20			
Environmental for *Vachelia reficiens*	Between Groups	.435	4	.109	.241	.911
	Within Groups	7.211	16	.451		
	Total	7.646	20			
Socio- economic *Prosopis juliflora*	Between Groups	.295	4	.074	.365	.830
	Within Groups	3.236	16	.202		
	Total	3.531	20			
Environmental *Prosopis juliflora*	Between Groups	.450	4	.112	.204	.932
	Within Groups	8.800	16	.550		
	Total	9.250	20			

The results in Table 4.30 (b) show that there is no statistically significant variance between the means of the responses in Waso division regarding the impact of the species on the socio- economic activities and the environmental components on spatial variation (F = 0.934; P= 0.469, F = 0.241; P= 0.911, F= 0.365; p= 0.830, and F = 0.204; p = 0.932) respectively. The test statistic was done at a significant level of 0.05, meaning that when the p value is less than 0.05 it indicated that there is a statistical significance difference between the spatial variation of *Vachelia reficiens* and *Prosopis juliflora*.

Table 4.30 (c): Analysis of Variance of Species Socio-Economic and Environmental Impacts in Sereolipi Division

		Sum of Squares	df	Mean Square	F	Sig.
Socio - economic for *Vachelia reficiens*	Between Groups	1.715	3	.572	2.284	.108
	Within Groups	5.255	21	.250		
	Total	6.970	24			
Environmental for *Vachelia reficiens*	Between Groups	.670	3	.223	.557	.649
	Within Groups	8.424	21	.401		
	Total	9.094	24			
Socio-economic *Prosopis juliflora*	Between Groups	1.022	3	.341	1.478	.249
	Within Groups	4.840	21	.230		
	Total	5.862	24			
Environmental *Prosopis juliflora*	Between Groups	1.724	3	.575	.860	.477
	Within Groups	14.036	21	.668		
	Total	15.760	24			

The results in Table 4.30 (c) show no statistical significance in variance between the means of the impacts which indicates that the results can be relied upon to make deductions that the presence of invasive plants in Sereolipi Division has no significant impact on the socio- economic activities and the environmental components on spatial variation (F = 2.284; p= 0.108; F= .557; P= 0.649; F=1.478; p=.249 and F= 0.860; P =0.447) respectively. The test statistic was done at a significant level of 0.05. This could be attributed to the fact that in Sereolipi division there is no interventions on the

invasive species despite some species having been introduced longer than in other divisions.

4.16 Sites Infested, Impacts and Causes of Plants' Invasion

The respondents indicated various sites affected by key species. Summary of the impacts were also indicated. These findings are presented in Table 4.31.

Table 4.31: Sites Infested by Key Invasive Plants

Species	Sites	Impacts
Vachelia reficiens	Grasslands	Displace plants, grass, blocks routes
Prosopis juliflora	Wetlands, roads, settlement	Blocks routes, depletes water, pasture,injurious,breeds mosquitoes
Sanseveria	Streams beds	Displace other plants
Cissus rotundifolia	Rangelands	Overtops *Vachelia tortilis*
Lantana camara	Homesteads	Poisonous to livestock, displace grass and other plants
Senna species	River beds, roads	Reduces roads visibility, reduce land size
Opuntia exaltata	Entire landscape	Reduce land size

Source: Author (2023)

The results in the Table 4.31 show that *Vachelia reficiens* was commonly seen in the grasslands and the main impact is that the plant displaces other plants and grass because of its canopy which tends to cut off light reaching the ground and increases the temperatures making it very difficult for the other plants to grow and thrive in the area. The results also showed that *Prosopis juliflora* is commonly found in the wet lands, roads and the settlement areas. This plant is exotic and was introduced to the area with the hope of helping to restore the degraded areas but the plant grows very fast and hamper other plants from growing. *Prosopis juliflora* has been noted to have high impact on the livestock and wildlife as it injures animals and cause diseases. The species thickets have also been noted to provide a hiding place for predators and this

has increased the human wildlife conflict besides making the areas inhabitable due to increase in population of mosquitoes. This calls for effective intervention methods that are able to assist in eradicating both species.

The study further sought to find out the main causes of plant species invasion leading to the faster spread and increase in the infestations of invasive plants. The household's heads, Focus Group Discussant and key informants were asked to give their views on their understanding of the main causes of increased infestation of the invasive species. The results indicated that the main causes of the infestations were land degradation which gives room for the invasive plants which are hardy and can grow in harsh conditions to thrive. The respondents also indicated that the high rate of seed dispersal by different animals as they migrate to new areas was also a critical cause of the high rate of spread. The increased livestock, human and wildlife mobility also play an important role in the dispersal and spreading of the seeds to other places where the plants are thriving.

Climatic changes is making it difficult for the growth and increase of other fodder crops and beneficial plants for livestock and wild animals. These changes in the climatic conditions have increased the mobility of the human and animals hence leading to depletion of grasslands and replacement by the invasive plants that can thrive in such harsh conditions. The changes in the climate lead to soil erosion and hence increased aridity which favour the invasive plants over the natural grasslands that are of benefit to the households. The *El Nino* year 1997 was linked by the respondents as the year invasive species became abundant in the sub-locations.

The other reason why these plants have a tendency of spreading out too fast is because the plants species are non-palatable and hence, they tend to thrive very fast as

they are not eaten by the livestock. The respondents further noted that the abundance of the species has occurred from the increase that has taken place in the last 10 years as a result of increased land degradation, increased movements accelerating dispersal, climate change, drought resistance, new introduction for various uses and non-palatability.

4.17 Management Interventions on Invasive Species

The respondents were required to rate various management interventions as either not effective or effective. The objective was addressed in three levels, first to establish the actors that were actively involved in the interventions' procedures, then the method of intervention and lastly the effectiveness of the intervention. The results were presented in the following sections.

4.17.1 Actors in the intervention process

It was also important for the study to identify the actors in the intervention process and establish the years the various actors in the intervention process have been in existence. The results are presented in Table 4.32.

The intervention process in the two divisions started in the year 1990-2022 for *Vachelia reficiens* and 2005-2018 for *Prosopis juliflora* with community and Northern Rangelands Trust (NRT) opening the gates of the interventions in 1990 and 2012 respectively for both species .Thereafter, the interventions peaked in 2017 through 2022 for most actors. The results show that there were 12 organizations including the community that were involved in the intervention process of the two species.

The organizations which have played a very critical role in the two areas was NRT, followed by KERRA, Red Cross Society, community initiatives while CODES (CBO)

has played a role in the intervention too as ranked accordingly. Kenya Rural Roads Authority, Grevy's Zebra Trust, Namunyak Community Wildlife Conservancy and ACTED (NGO) have also operated in the locality in the interventions of the species. The interventions however, have not been consistent as dictated by availability of funds. In regard to *Prosopis juliflora*, the main Actor in the management of the species is the Local community together with Ngutuk Engiron Conservancy and NRT. This implies that there were efforts by various organizations to assist in the management of the species.

Table 4.32: Actors in the Intervention and Year of Operation

Actors	***Vachelia reficiens* 1990-2022**		***Prosopis juliflora* 2005-2018**	
	Frequency	**Division**	**Frequency**	**Division**
Ngutuk Engiron Community Wildlife Conservancy	3	Waso	1	Waso
Meibae Community Wildlife Conservancy	4	Wamba	0	
Namunyak Community Wildlife Conservancy	3	Waso	0	
NRT	23	Wamba Waso	1	Waso
Grevy's Zebra Trust	3	Waso	0	
ACTED (NGO)	6	Wamba	0	
Rural-Urban Roads Authority	9	Wamba	0	
KERRA	20	Wamba	0	
CARITAS (NGO)	5	Wamba	0	
Community	10	Wamba	2	Waso
CODES (CBO)	10	Wamba	0	
Red Cross Society	15	Wamba	0	Waso

Source: Author (2023)

The results in Table 4.32 were confirmed by the respondents who participated in the study. The results indicated that the members of the groups were able to identify eight groups of organization that play an important role in the management of the invasive species in the area. The results indicated that NRT which is one of the existent and community wildlife conservancies' umbrella organizations, was involved for long in the management of the species including capacity building to sensitize the communities on the most appropriate methods of controlling and managing the species. The other organization was FAO which supported the intervention process through funding for manual cutting and reseeding of the areas cleared of the plants. This played a very important role as it helped the pastoralist who have limited financial support to access funds that assist them make informed decisions about management of invasive plants. The other organization cited was CODES which supported the residents by providing funds for manual clearing of the bushes and the trees. The other organizations according to the results of the interview were ACTED, Community Conservancies, CARITAS, VSF and KRCS. This supports the findings of Adoyo et al. (2022) who reported the need for coordination and targeted management of invasive species.

4.17.2 Management interventions methods

The study further assessed existence of any interventions in the control of the two species that are considered invasive. Figure 4.9 illustrates the interventions graphically.

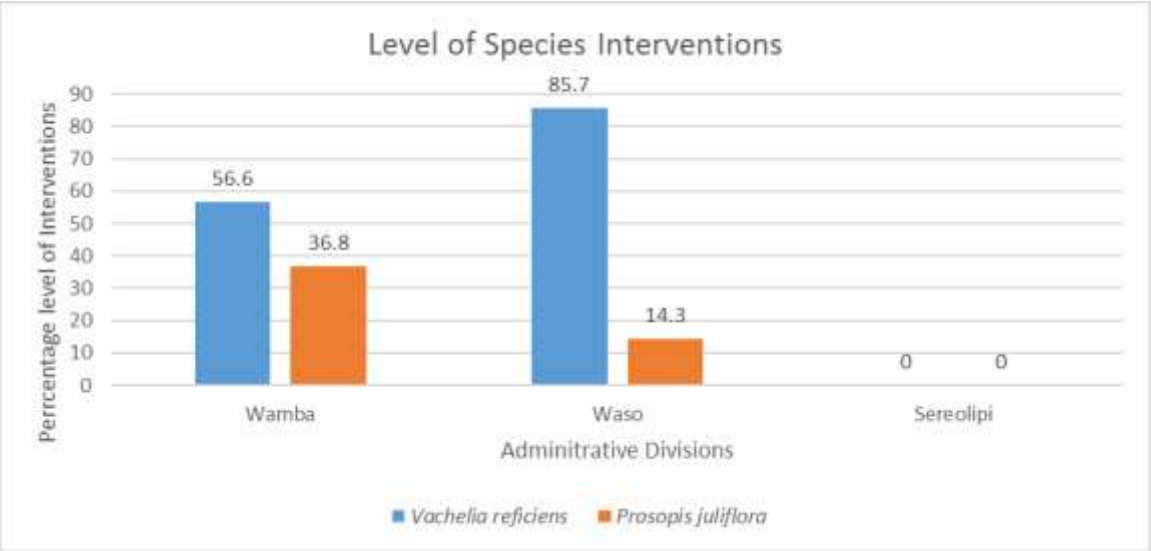

Figure 4.9: Level of species interventions in the divisions

The results in Figure 4.9 shows that in all the three Divisions, the interventions in the management of *Vachelia reficiens* species was higher at 85.7% in Waso and 56.6% in Wamba. There was no intervention of the species in Sereolipi, this is attributed to the fact that the species are spread widely in Waso and Wamba and also the species have been there for a longer time as from 1995. This indicates that the impact has been felt in the two division of Waso and Wamba calling for intervention. On the other hand, the management interventions for *Prosopis juliflora* were seen to be higher at 36.8% in Wamba and 14.3% Waso. Again there was no known intervention in the management of the species in Sereolipi. The results revealed that in both Wamba and Waso, the management interventions of the species were at a higher level for both *Vachelia reficiens* and *Prosopis juliflora.*

This shows that *Vachelia reficiens* had received more attention than *Prosopis juliflora* in terms of management intervention. This could be attributed to the fact that *Vachelia reficiens* has been in existence for a longer time and also because of its natural existence.. *Prosopis juliflora* is still new to most of the areas because it is exotic and hence the interventions are not much. Previous analysis indicated that *Prosopis juliflora* was reported invasive to most of the areas in 2005.

4.17.3 Effectiveness of methods used in the interventions

The respondents were asked to respond to various methods of intervention and rate them accordingly. The various intervention methods were cutting at various level of the plant growth, burning, trimming, uprooting or a combination of two methods. Figure 4.10 illustrates graphically the effectiveness of the most commonly used methods of eradicating the two invasive plants in the sub-county.

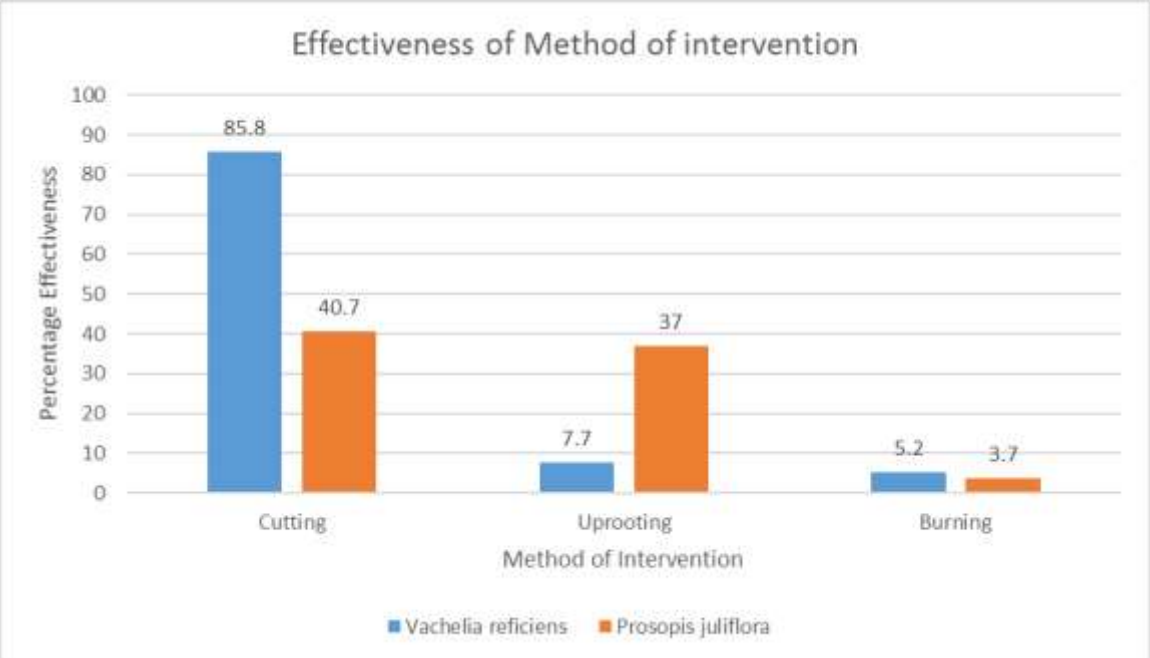

Figure 4.10: Effectiveness of methods of intervention

Figure 4.10 shows that the most effective method of eradicating the species was cutting at 85.8% for *Vachelia reficiens*, On the other hand, 40.7% of the respondents

indicated that cutting was the most effective method of managing the effect of *Prosopis juliflora.* Uprooting was noted to be effective at seedling stage and made more effective when cut material was burnt.

4.17.4 Impacts of the species on household livelihoods in the absence of interventions

On the assessment of the impact of invasive species on households' livelihoods in Samburu East Sub-County, a majority of households reported that the lack of intervention in controlling the invasive species has resulted in increased migration in search of fodder for their livestock, as well as a reduction in productivity and quality of livestock hides and skins due to injuries caused by thorns from the invasive species. The study also found that livestock consume the invasive species by accident, resulting in increased loss of livestock, and subsequently, income and livelihoods of households. This has led to increased poverty levels among the households, exacerbated by decreased food sufficiency caused by erosion. Additionally, water scarcity had become prevalent due to the invasive species depleting water resources in streams and water pans.

Respondents further confirmed some successes of previous interventions though on a limited scale as; enhanced land productivity and vegetation cover in areas freed of invasive plant species, enhanced livestock productivity due to availability of pasture and enhanced livestock markets as reclaimed areas are in use as livestock fattening areas before they are sold.

When asked to indicate what can be done to sustainably reduce the invasive, most interviewees indicated that the only solution to eradicate the plant is to cut, uproot them, burn them and allow the natural grasslands to grow again. The respondents also

noted that there is need to sensitize the communities on the appropriate ways to eradicate the species and adhere to post management practices like reseeding, improved governance on imposition of fines and penalties for those flouting deferred grazing systems and rules and eradication efforts of the invasive plants. They summed up these management aspects to the need to have a management plan to guide on sustainable management of the rangelands. There were calls for the government to come up with a policy that can assist the community members effectively participate in the eradication of the species in the area.

This was more so as 82% of respondents indicated that *Vachelia reficiens* was disastrous while 36% indicated *Prosopis juliflora* as disastrous and their abundance was increasing, 90% and 55% for *Vachelia reficiens* and *Prosopis juliflora* respectively. Due to this 90% of the respondents indicated the need to eradicate *Vachelia reficiens* and 62% indicated *Prosopis juliflora.*

4.18 Qualitative analysis of methods of interventions

According to the results gathered from the three categories of interviews undertaken in the Sub-County, *Vachelia reficiens* was identified as the predominant species, particularly in Wamba and Waso areas, compared to Sereolipi. The participants also noted that the species was difficult to eradicate due to its established presence in the area and woody morphology, and recommended cutting and burning as the most effective control method based on a prescribed practice for instance progressive selective cutting accompanied by reseeding with suitable species to avoid denudation of the rangelands. Development of a management plan suffices.

According to the respondent, the species present in the area are difficult to eliminate due to their unpalatable nature to livestock and lack of meaningful economic use at

present. The invasive plants are not good fodder for the livestock, therefore considered a problem to the society, as the species are not palatable to the livestock which is one of the reasons why they spread fast and are not easy to eradicate and that no drought ever within living memory has made these species to dry up as they are drought tolerant hence the spread and establishment. No other natural process has been known to counter the spread of *Vachelia reficiens* and *Prosopis juliflora*. This view supports Gichua et al. (2013) hypothesis on increase of invasive species as a result of lack of natural enemies or regulators.

The study highlights the significance of cooperation and efficient management of respective areas by all households for the control method's effectiveness. By doing so, invasive plants will not be allowed to reach maturity, preventing the dispersal of their seeds by water, livestock, birds, and wild animals.

Respondents reiterated the process of eradicating invasive plants needed a lot of commitments and concerted efforts from the community members and stakeholders. Thery reported the existent of by-laws made by the community to encourage cutting of the species and prevent their introductions in the area. Those flouting have been fined 2-3 goats per offence. This ensured consistent control of the invasive plants and stopped further dispersal of seeds. The use *Vachelia reficiens* and *Prosopis juliflora* for making the hedge (fencing the compound) will provide an ideal opportunity of utilizing the plants for economic benefits. This supports similar findings of Gichua et al. (2013), and Adoyo et al. (2022) on the need to have a coordinated approach to counter the invasive as well as the cooperation required from stakeholders as suggested by Essl et al. (2020).

The respondents noted that the invasive plants have presented numerous challenges to households, in addition to the harsh weather conditions resulting from the arid and semi-arid (ASAL) nature of the divisions.

Further probing indicated that most of the interventions were done for the purpose of restoration of rangeland through clearing and reseeding in wildlife conservancies, the other intervention included community capacity building where the community members are sensitized through training. The other method of intervention included the development of grazing plans where the communities are currently grazing their animals and deferred grazing in other areas. What was clear was that none of the organization has engaged on research to try and clearly bring out the concept of the effect of these invasive plants on the socio- economic and environmental aspects.

Respondents indicated their role in the management of the invasive species in the sub-locations. They felt that their contribution was important because as they have an important role in the control of the invasive species. The results showed that most of the respondents over 60% participated by offering labour where they were paid for the work done in the process of eradication, 58% said that they participated as volunteer while another 67% indicated that they participated as part of communal work restore their localities livestock and wildlife conservation.-This clearly shows that the respondents were actively participating in the management of the invasive species but require support from the government and environment stakeholders. The responses supports the findings by Abdulahi et al. (2017), Gordon and Arne (2013), and Tessema (2012) who noted that eradication and utilization practices in Ethiopia include conversion of infested areas into irrigated agriculture, charcoal production and flour production to feed livestock.

The respondents indicated that the most common stage of plants' control in the area was either at maturity stage or at any stage. Additionally, eradicating the species during the dry season was found to be the most effective approach, although some participants also mentioned that control can be done at any time of the year depending on interests of stakeholders on community support. This suggests that eradication during the dry season is particularly effective because the plants die quickly due to water stress.

Further analysis to assess whether the process of managing the eradication was coordinated and well supervised, majority of the respondents agreed that the process was well supported by the organization and the community elders. They indicated that the process was well supervised by either the staff from the organizations concerned or from the community elders. However, they noted that they face a lot of risks in the process, especially the risk of being hurt by wild animals, being pierced by poisonous thorns from the invasive plants, being hurt by the falling branches and poor protective clothing to access thickets. This has affected the process of eradicating the invasive plants hence making the spread very fast and challenging.

On other ways in which the species can be eradicated, the respondents indicated that these species are drought resistant and hence cannot be eradicated by the harsh weather caused by drought. The two species *Vachelia reficiens* and *Prosopis juliflora* are very resistant to the dry spell and are not palatable to animal hence they tend to thrive. So far there are no other natural ways by which the invasive plants can be controlled.

4.19 Hypotheses Tests on Species Mean Impacts

The statistical analysis utilized the chi-square test of association to test the hypothesis. The test was conducted at two levels. Firstly, an analysis of variance was employed to assess the variance between the means of the impact of the two species on socio-economic activities, environmental components, and spatial variations of impacts.

4.19.1 Analysis of variance (ANOVA) of species mean impacts

The results were subjected to analysis of variance to test the differences in the means of the responses and the results are presented in Table 4.33.

Table 4.33: Analysis of Variance of Mean Variance of Species Impacts

Impacts		Sum of Squares	df	Mean Square	F	Sig.
Socio economic	Between Groups	2.860	2	1.430	3.184	.045
	Within Groups	53.435	119	.449		
	Total	56.295	121			
Environmental	Between Groups	1.681	2	.841	1.015	.366
	Within Groups	98.563	119	.828		
	Total	100.244	121			
Spatial	Between Groups	22.467	2	11.233	10.435	.000
	Within Groups	128.102	119	1.076		
	Total	150.568	121			

The results in Table 4.33 shows the variance between the means of species impacts is statistically significant.This indicates that the results can be relied upon to make deductions. The test statistic was done at a significant level of 0.05. The results in the table shows that the F statistics for the mean variance between the invasive species

and the socio-economic activities of the households was 3.184 with a p value of 0.045. This implies that since the p value is less than 0.05 then the variance was statistically significant between *Vachelia reficiens* and *Prosopis juliflora.* The results further indicates that the F statistics *(F= 1.015.; p, .366)* for the mean variance between the impact of the invasive species on environmental components in the sub-county. The results indicated that the difference was not statistically significant since the p value is higher than 0.05. In regard to the impact of *Vachelia reficiens* and *Prosopis juliflora* on the spatial variation, the results also show a statistical significance variation in the means since the (F= 10.435; p, .000) and the p value is less than 0.05.

4.19.2 Chi square test of association (χ2) of species socio-economic impacts

To assess the relationship between the prevalence of invasive species and their impact on socio-economic activities in Samburu East Sub-County, a chi-square test of association was conducted. Based on the statistical analysis, null hypothesis, **Ho 1**: *that there are no significant impacts of Vachelia reficiens and Prosopis juliflora on the socio-economic activities of the residents in Samburu East Sub-County* was tested. The results of the chi square test of association are presented in Table 4.34.

Table 4.34: Chi-Square Test of Association for Species Impacts on Socio-Economic Activities

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	618.388[a]	323	.000
Likelihood Ratio	244.208	323	1.000
Linear-by-Linear Association	12.635	1	.000
N of Valid Cases	122		

The results show a strong and statistically significant association between the impact of the invasive plant species and the socio-economic activities of the households in the study area. This is given by the chi square value **(χ^2 = 618.388)** and the (P value < 0.05). Therefore, the null hypothesis is rejected, the alternative hypothesis that there is an association between the variables was accepted, implying that *Vachelia reficiens* and *Prosopis juliflora* have a significant impact on the socio-economic activities of the households.

4.19.3 Chi square test of association (χ2) of species impacts on environmental components

The study tested the association between the invasive species and the impact they have on the environmental components in Samburu East Sub-County. The chi square test statistic between environmental components and the prevalence of the invasive species was computed and presented in Table 4.35. The null hypothesis, **Ho 2:** *there are no significant impacts of Vachelia reficiens and Prosopis juliflora on environment in Samburu East Sub-County* was tested.

Table 4.35: Chi-Square Test of Association for Species Impacts on Environmental Components

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	402.566[a]	273	.000
Likelihood Ratio	216.846	273	.995
Linear-by-Linear Association	10.057	1	.002
N of Valid Cases	122		

The results presented in the Table 4.35 shows that there is a strong statistical association between the invasive plants *Vachelia reficiens* and *Prosopis juliflora* on

the environmental components in the study area as shown by ($\chi^2 = 402.566$) and (a p value < 0.05). The results shows that the null hypothesis is rejected and the alternative hypothesis accepted that there is a significant impact between the two species on the environmental components in the study area.

4.19.4 Chi square test of association (χ^2) of species spatial variations of impacts

The study further tested the association between the invasive species and the impact on spatial variation in Samburu East Sub-County. The chi square test statistic between spatial variations together with the prevalence of the invasive species was computed and presented in Table 4.36. The null hypothesis; **$H_{O\ 3}$**: *There are no significant spatial variations of the impacts of Vachelia reficiens and Prosopis juliflora in Samburu East Sub-County* was tested.

Table 4.36: Chi-Square Tests of Association of Species Spatial Variation of Impacts

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	93.823[a]	30	.000
Likelihood Ratio	87.542	30	.000
Linear-by-Linear Association	37.431	1	.000
N of Valid Cases	122		

The results presented in Table 4.36 shows that there is a strong statistical association between the invasive plants *Vachelia reficiens* and *Prosopis juliflora* on the Spatial variations of impacts in the study area as shown by ($\chi^2 = 93.823$) and (p value < 0.05). The results shows that the null hypothesis is rejected and the alternative

hypothesis that the impacts between the two species vary over space in the study area was accepted.

4.20 Chapter Summary

The synopsis chapter of this study focused on the analysis and presentation of the collected data. To begin with, Response rate was assessed to ensure the appropriateness of the the views obtained. Gender representation was considered to determine the involvement of the respondents. The demographic factors of the respondents were analyzed to assess the quality of the respondents. Statistical tests were conducted to verify the relationship of the study variables, and differences in means and responses were assessed. The findings were presented using tables and graphical figures, and clear statements of the findings were provided. The study demonstrates the significant impact of invasive plants on socio-economic attributes of Samburu pastoralist community and the environment in Samburu East Sub-County, highlighting the urgent need for proactive interventions to safeguard the environment and the socio-economic aspects of livelihoods of the residents.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS OF THE STUDY

5.1 Introduction

This study was conducted in Samburu East Sub-county located at the eastern parts of Samburu County, in the Republic of Kenya. The sub-county is an Arid and Semi-Arid land. The basic unit of data collection was the household. The study secured a response rate of 100 % of adult residents of both gender targeted for the study and 80% of them have lived in the area for more than 20 years. The respondents were knowledgeable and conversant with the invasive plant species and their impacts in the sub-locations of residence since 1990. The economic mainstay of the respondents was livestock production whose main threats are; drought, livestock diseases, invasive species and human-wildlife conflicts. The main threats to the environment in the sub-locations are; Soil erosion, invasive plants, drought and deforestation.

The aim of the study was to assess impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio-economic activities of the residents and selected components of the environment in Samburu East Sub-County, their spatial variations of impacts in divisions and management interventions. Set objectives of the study were to; determine the the impacts of *Vachelia reficiens* and *Prosopis juliflora* on socio-economic activities of the resident community; assess the impacts of *Vachelia reficiens* and *Prosopis juliflora* on selected components of the environment; examine spatial variations of impacts of *Vachelia reficiens* and *Prosopis juliflora,* and evaluate effectiveness of on-going management interventions on *Vachelia reficiens* and *Prosopis juliflora* in theSub-County.

Findings of the research were summarized to draw inferences and recommend the way forward for sustainable management of invasive plants. Suggestions to further

research also made. Focus Group Discussions and Key Informant Interviews to get additional information on the impacts of the two invasive species at a response rate of 100% were also undertaken.

5.2 Summary of the Findings

The results show the impact of the species on socio-economic activities vary among the two species. *Vachelia reficiens* posing significant impacts over *Prosopis juliflora* in the sub-locations. On a Likert scale rating of impacts, *Vachelia reficiens* scored major impacts on; governance, local transport, income and expenditure; moderate impacts on livestock production and minor impacts on natural resource use conflicts. *Prosopis juliflora* had moderate impacts on governance and livestock production while minor impacts on income and expenditure, local transport and natural resource use conflicts. The results show that the impacts of the species on governance in terms of grazing systems and rules, had constrained management of natural resources and their access in the sub-county. This was due to breakdown of governance systems which regulates environmental management in the sub-county.

The plants had substantially reduced the size and quality of land available for livestock production due to encroachment of grasslands and inducing widespread gully erosion. This had caused frequent livestock movements to far areas for pasture and water. This had denied residents continued access to livestock products and income for their sustained livelihoods. This had made the households to increase expenditure on commercial foodstuffs and migrations related costs. The plants form impenetrable thickets in areas of high infestations denying residents' uninterrupted use of natural resources such as water and social services such as schools and healthcare facilities.

The blockage of resource use routes has led to increase in natural resource use conflicts including human-wildlfe conflicts. The conflicts have come to increase costs of conflicts resolutions thus reducing household income for other basic needs. Further Chi square statistical analysis showed that the impact between the species on socio-economic activities in the Sub-County was statistically significant (χ^2 = 618.388; P value 0.000 < 0.05). The results were also confirmed by the Key Informants and the Focus Group Discussions, where majority of the respondents were in agreement that the invasive plants affected the socio-economic activities of the households as manifested by livestock mobility and frequent migrations exposing residents to conflicts.

The assessment of the impacts of *Vachelia reficiens* and *Prosopis juliflora* on selected environmental components in the Sub-County, show influence of the species on environmental components to vary among the species. *Vachelia reficiens* again recording significant impacts over *Prosopis juliflora*. On a Likert scale rating of impacts, *Vachelia reficiens* scored; severe impacts on natural regeneration; major on grasslands while moderate on water availability, wildlife and land productivity. *Prosopis juliflora* scored; moderate impacts on natural regeneration and water availability and minor impacts on wildlife, land productivity and grasslands. Both *Vachelia reficiens* and *Prosopis juliflora* affected natural regeneration of other plants and the availability of water to a great extent. This was due to their canopies which choked other plants and their deep-fibrous roots believed to drain more water in the area. *Prosopis juliflora* in particular had substantial adverse impacts on wetlands.

The loss of natural regeneration has been singled out by respondents to increase soil erosion in the area thus responsible for the loss of productive potential of the land in the sub-county. Together with the depletion of grasslands, the plants have drastically

reduced wildlife balance in the area leading to the presence of more predators than herbivores. These impacts have catalyzed the negative impacts of the species on socio-economic activities. Further, alterations in the environmental components has also affected the production of food and hence increased the poverty levels among the households.

Their impacts have caused displacement to local extinction of major flora and fauna leading to homogenization of ecosystems in areas of major infestation. This has reduced the quality and flow of ecosystem goods and services long depended by the community. Declining honey and hunger foods (wild fruits, tubers, gums and resins) are clear testimonies from the members of the community on the negative impacts of the plant to the environmental components, social and economic systems in place. The Focus Group Discussions revealed similar results indicating that the invasive plants have contributed to depletion of the grasslands, ecosystem goods and services. This had increased level of conflicts and migrations in the area. The chi square analysis results indicated that there was a statistically significant association between the impacts of the invasive plants on the environmental components in the Sub-County ($\chi 2$ = 402.566[a]; p value 0.000 < 0.05).

On examination of the spatial variations of impacts of *Vachelia reficiens* and *Prosopis juliflora* in the study area. *Vachelia reficiens* was reported to have been indigenous but introduced through livestock and wildlife movements to the Sub-County before 1960s from the neighbouring Isiolo County while *Prosopis juliflora* was introduced in 1980s by GTZ Project (NGO) to rehabilitate degraded areas and protect water points from soil erosion and siltation.

The study was to examine; the average time the species have been present and invasive in the area; their average socio- economic and environmental impacts per division. The results show that in Wamba impacts of *Vachelia reficiens* on socio-economic activities were; moderate in Wamba and Sereolipi, and major in Waso. This implies the socio-economic activities in Waso are highly affected by the invasion by *Vachelia reficiens*. The spatial variations analysis of impacts of *Vachelia reficiens* on the environmental components showed that; in Wamba impacts were moderate and major in Waso and Sereolipi. This implies that the environmental components in Waso and Sereolipi were highly affected compared to Wamba Division.

The study in addition, assessed the spatial impacts of *Prosopis juliflora* on socio-economic activities of the three divisions. The results show that in Wamba the impacts were insignificant and minor in Waso and Sereolipi. This implies that the economic activities in Waso and Sereolipi are more affected compared to Wamba Division. The Spatial variations of environmental impacts of P*rosopis juliflora* showed that in Wamba and Waso divisions the impacts were minor and major in Sereolipi. This implied that the environmental components in Sereolipi are highly affected by the invasion.

The chi square test confirms that the two species have a significant impact on the spatial variation of the socio-economic and environmental impacts in the area ($\chi 2$ = 93.823^{a} ; p value $0.000 < 0.05$)

The fourth objective sought to assess the effectiveness of various methods used to manage the species. The results show that cutting down the plants and burning them was the most appropriate method of intervention. Further analysis indicated that prescribed cutting at mid-height of the species was the most effective method of

eradication. In addition to this, *Vachelia reficiens* had attracted more interventions compared with *Prosopis juliflora* in both Wamba and Waso Divisions. Sereolipi Division reported no actor or intervention. Majority of the respondents agreed that the process was supported by the organizations and the community but required additional resources and a guided management to sustain eradication of the plants.

5.3 Conclusion

Vachelia reficiens and Prosopis juliflora have varying negative impacts on socio-economic activities, environmental components and their impacts vary with space (Divisions). Sereolipi and Waso division being the most affected administrative divisions. Prescribed cutting is the most used and effective method of controlling the two invasive plants. *Vachelia reficiens* due to its spread, expansion and major negative impacts attracting more interventions though insufficient from stakeholders and the resident community in Wamba and Waso Divisions. Sereolipi Division recorded no actor or any form of intervention on both species of focus. The two species generally have claimed and continue to claim by degrading, indigenous vegetation, suitable land for water, livestock and wildlife uses, therefore diminishing the ecosystem integrity to sustain a healthy and productive rangelands systems in the county. Further, they have caused breakdown of governance structure leading to frequent social disorders and conflicts among the residents. *Prosopis juliflora* has claimed critical wetlands of the sub-county used as sources of water, salt licks and dry season grazing. The invasions call for attention and further research on their expansions.

The results of the impact of the two species on socio-economic and environmental components and variation among divisions show statistically significant impact on Chi square tests of association on the households in the Sub-County. Therefore, the

null hypotheses on non-existence of significance impacts of *Vachelia reficiens and Prosopis juliflora* on; *socio-economic activities, environment and spatial variations of the impacts of their impacts in Samburu East Sub-County* are rejected and the alternate accepted at; **(χ^2** = 618.388; P value 0.000 < 0.05; $\chi 2$ = 402.566[a]; p value 0.000 < 0.05); $\chi 2 = 93.823^a$; p value 0.000 < 0.05) respectively.

Finally, the study concludes that the invasive plants needs a comprehensive and coordinated management interventions processes to mitigate the spread and impact of invasive species in order to safeguard environment, social and economic attributes in the study area. This calls for urgent and proactive intervention measures to help in eradicating the species to safeguard environment and socio-economic activities of the residents. The interventions will support the Government of Kenya commitments and attainment of environmental sustainability and economic advancement as pledged and envisioned in Sustainable Development Goals (SDGs), Vision 2030, Green Economy Strategy Implementation Plan 2016-2030 (GESIP), Bottomup Economic Transformation Agenda (BETA), 30% tree cover by 2032 and Kenyans rights to clean and healthy environment as enshrined in the Kenya Constitution 2010. The interventions will further aid the Kenya Government on meeting its international obligations as obliged in the International Plant Protection Convention (IPPC) and Convention on Biological Diversity (CBD) on biodiversity conservation for sustainable development among member States.

5.4 Recommendations

i. Due to the harmful impacts of Vachelia reficiens on socio-economic and environmental aspects in the entire sub-county and the community sustained concerns on the need to eraidicate it due to its disastrous impacts, the Government of Kenya in collaboration with County Government of Samburu

should consider and declare *Vachelia reficiens* as a harmful native invasive plant and enroll the plant in the inventory and register of invasive plants in the county and Kenya and recommend its incorporation in the Global Register of Invasive Species . This as a tool of invasive plants management, will influence the County Government of Samburu and development partners in the development of a sustainable government-community led eradication programme of the plant in the sub-county.

ii. The resident community in conjunction with stakeholders have already initiated eradication plans for *Vachelia refciciens* and *Prosopis juliflora* in some areas to safeguard biodiversity and their livelihoods mainly in Wamba and Waso divisions. They have organized themselves into groups to help in sustainable clearing of the plants. There is need for the County Government of Samburu to Capacity build the communities on sustainable management of the plants. This will fasten eradication efforts and prevent their further spread and establishment. Sereolipi division should be prioritized as it is the most affected division due to non-existent of support organizations and community interventions.

iii. On governance, the resident community had formed and operationalized by-laws on clearing of invasive plants and deferred grazing to allow for rehabilitation of cleared areas. Deliberate attempts for instance incorporating by-laws or resolutions on invasive plants in county structures should be made by Samburu County Government to encourage the utilization of *Vachelia reficiens* and *Prosopis juliflora* to reduce their population and the accompanying negative impacts on socio-economic and environmental systems. Revival of traditional land governance structures and systems for the rangelands to promote sustainable management of invasive plants in support of sustainable community wildlife

conservancies and pastoralism should be prioritized by the County Government of Samburu.

iv. Community efforts in place should be picked and upscaled by the County Government of Samburu and be integrated in the formulation and operationalization of a government-community led sustainable eradication Programme for *Vachelia reficiens* and *Prosopis juliflora* in the entire sub-county.

v. To regulate and sustain current community initiatives on invasive plant management, there is need for the Development of an Invasive Plant Management Plan by Samburu County Government and development partners to guide and effect the sustainable management of invasive plants across the sub-county as current efforts are non-existent in Sereolipi division. This can be done by developing an inventory of actors or organizations involved currently on eradication activities and spread actors equitably for the interventions to cover all divisions in the sub-county and other vulnerable parts of the county.

vi. Post-management practices on areas cleared of invasive plants were evident in the sub-county, therefore Samburu County Government-should prioritize the up scaling of reseeding in these areas freed of invasive plants using indigenous grass and multipurpose trees species and integrate with soil and water conservation practices to spur environmental sustainability in support of Sustainable Development Goals (SDGs), Bottom up Economic Transformation Agenda (BETA) Kenya's Vision 2030 and Kenya's commitment on attainment of 30% tree cover by 2032.

vii. To sustain the management of invasive plants was attested by the respondents to be backed by the government for meaningful long term solutions to the menace

of invasive species and offer benefits to the community. Therefore, Samburu County Government should formulate a stand-alone policy that promotes research, education, sustainable utilization and eradication of invasive species with a focus on sustainable eradication of invasive plant species to mitigate climate change and enhance environmental sustainability as the impacts of invasive plants have been reported to worsen with climate variability. The policy should recognize and encourage voluntary but guided eradication initiatives, resource allocation and mobilization, research, education and extension on invasive species to enhance stakeholders' uptake of the management of invasive plants in focus for sustainable development.

5.5 Areas for Further Study

Due to the revelation of the existent of many types of invasive plants in the sub-county for long, there is also need to have an evaluation of the ground situation before and after (spatial-temporal analysis) of the invasion in order to fully have an understanding on trends andthe impact of the invasion on the Socio-economic activities, environmental components and spatial-temporal impact variation in the sub-county.

On conservation status of affected flora and fauna, there is need for research to determine the impact of the invasive plants on biodiversity in the Sub-County in order to determine the conservation status of major flora and fauna.

Research on cost-effective method of progressive and sustainable eradication of invasive plants and rehabilitation of areas freed of invasive plants to spur environmental sustainability is a study area to be explored.

Research on integrated and cost-effective post management practices on land freed of invasive plant species is recommended to allow for recovery and enhanced productivity of land claimed by invasive plants for the conservation of biodiversity.

Identification of invasive species and mapping in the entire county to know their distribution and abundance in order to guide on their sustainable management and stop further spread is a study area worth an undertaking.

The role and impact of climate change as a thematic area currently in the world on proliferation of invasive plants in the sub-county and their management is an important research area.

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APPENDICES

APPENDIX I

RESEARCH STATUTORY AUTHORIZATIONS

(a) National Commission for Science, Technology and Innovations License

(b) Ministry of Education Letter

(c) Maasai Mara University Letter of authorization

(d) Ministry of Interior and Coordination of National Government Letter

(e) Letter of Authority from the Office of the County Governor

APPENDIX II

RESEARCH INSTRUMENTS

(A) HOUSEHOLD HEADS QUESTIONNAIRE

My name is Mr. Patrick Pureina Lekenit, a Master of Science student at Maasai Mara University, Narok, Kenya. I am assisted by Mr./Mrs./Ms.……as an/enumerator/ward representative/research Assistant in data collection for the study through interviews. The study will be undertaken in the sub-locations of Samburu East Sub-County.

The purpose of the survey is to obtain data on how *Vachelia reficiens* and *Prosopis juliflora* has impacted on your **socio-economic activities and the environment of the sub-location you live in. The research also will examine some management interventions** currently being undertaken. You were chosen for the exercise because you are a resident of the sub-county. All of the answers you provide in this survey will be kept anonymous and confidential.

Subject to you agreeing to participate, the interview will take at most 2 hours and you have the right to continue to participate or withdraw from the interview.

Village…….

Sub Location……..

Location…….…….

Division……..…….

Date of interview…….**Household Questionnaire No**……..……

SECTION A: BACKGROUND INFORMATION OF HEADS OF HOUSEHOLDS

1. Gender?

(a) Male (b) Female

2. Age in years?

3. Literacy level?

(a) Primary (b) Secondary (c) tertiary (d) None

4. Marital status?

(a) Married (b) Single (c) Widowed (d) Divorced

5. Hierarchy in the Family/Position?

(a) Household Head (b) Spouse (c) Son/Daughter

6. How many years have you lived in the sub-location?

……...

7. (A) what are the key economic activities you engage in as a household?
.....
.....

(B) Based on your answer in 7(A) above, which is the main economic source of your livelihood as a Household?

……
…

Section B: Information and Impact of Invasive Species in the Sub Location.

8. State major threats affecting your main economic mainstay as stated above?

……
……..

9. Have you encountered some environmental issues while living in the sub-location? If yes, list those you believe are key??

……

……..

10. **(A)** Are you aware of an invasive plant species? (Yes) (No)

(B) If **No** proceed to **Section C** and if **yes**, how can you describe them or what makes you believe that they are invasive? Choose from the list below, the characteristics you knowof?

(i) Unusual Widespread distribution from the known **(ii)** dominates or overtops other vegetation **(iii)** Risk to humans and animals **(iv**) Displays negative impacts on grazing systems **(v)** Thickets are difficult to move through **(vi)**Other (specify)……

(C) If **yes**, do you know some of theinvasive or spreading plants in the sub-location?

Yes **No**

(D) If **No** skip to to **Section C** and if **yes**, state **key** invasive species in the sub location and their origin?

Invasive Plant Species	Place of Origin		
	Natural/Indigenous	**Exotic/Introduced from elsewhere**	**Unknown**

Section C: Impacts of *Vachelia reficiens* and *Prosopis juliflora* in the Sub Location

11. **(A)** *Vachelia reficiens* (**Lchurai** in Samburu language) has drawn the attention of the media and environment actors as a plant of concer! Are you in agreement with this perception? Yes No

(B) If **No** go to to question **14** and if **yes**, what makes you believe that it is invasive?

(i) Unusual widespread distribution (ii) dominates and overtops other plants (iii) Risky to health of humans and animals (iv) Negatively impacts on grazing systems (v) Has unpassable thickets (vii)Other (specify)……

(C) How many years have you interacted with *Vachelia reficiens* in the Sub Location (**Compare with Q. 6 and 11 C to get accurate time)**?

……

(D) Which **year/time** has *Vachelia reficiens* concerned you as an invasive plant in the sub location (Make reference to **Q.6)**? .....

12. **(A)** Has *Vachelia reficiens* **negatively impacted** on your socio economic systems? If so, **rate Impacts** based on your experience in the sub location as stated below (See Likert rating scale provided below)?

Socio-Economic Activity Impacted	**Answer**		**Perceived Magnitude of Impacts**				
	Yes	**No**	**1 Insignificant**	**2 Minor**	**3 Moderate**	**4 Major**	**5 Severe**
Governance-grazing systems and rules							
Livestock production-yields, health, diseases, injuries, trapping							
Income and expenditure systems -sources, diversity, costs							
Local transport/Access to services-health, education, grazing fields							
Natural resource use conflicts or disputes							

Source: Screening checklist (Nackley et al., 2017),

(B) Based on your ratings above, give an account of impact scenarios or live experiences for each impact categories indicated below? **Refer to the above table for rated impacts to be considered in each of the below impacts**!

Governance systems (Nkitoria in Samburu language)

……
……

Livestock production

……
……

Impact on household Income

……
……

Impact on household expenditure

……
……

Local transport/movement

……
……

Natural resource use conflicts/Disputes

……

(C) While living in the sub-location, have you ever changed your economic activities because of the the negative impacts of *Vachelia reficiens*? Yes No

(D) If **yes,** which are this/these economic activity/ies you have changed to**?**

……

(E) In which aspects have the socio-economic activities you changed to (12D) improved your income?

……

13. **(A**) Give an account of *Vachelia reficiens* (**Lchurai** in Samburu language) **impacts on** the environment of the Sub-Location and **rate impacts** according to your perception as stated below (See Likert rating scale provided below)?

Component of the Environment Impacted	Answer		Perceived Magnitude of Impacts				
	Yes	No	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Severe
Water availability							
Impacts on Wildlife							
Land productivity(Soil erosion)							
Grasslands							
Natural regeneration of plants							

Source: Screening checklist (Nackley *et al*., 2017

(B)Based on you rating above, explain real impact scenarios or live experiences for each impact categories**?-**make references to the above table for information to be considered in each of the below impacts?

Impacts on water resources

……
……

Impacts on Wildlife

……
……

Land productivity/Soil erosion impacts

……
……

Impacts on grasslands

………
……

Impacts on plants natural regeneration/recruitment potentials of other plants

……
……

14. (A) *Prosopis juliflora* commonly known as Mathenge (**Mitilaya** in Samburu language) has been considered in other areas of Kenya and the world as aninvasive plant! Has these plant species been invasive in the Sub Location?

Yes **No**

(B) If No proceed to **Q.15** and if **yes,** what makes you believe that it is invasive?

(i) Unusual Widespread distribution (ii) dominates o rovertops other vegetation (iii) Risky to humans and animals (iv) Negatively impacts on grazing systems (v) Has unpassable thickets (vi) invasive in other sub counties (vi) Other (specify)……

(C) If **No** go to **Q 17**, If **Yes**, for how many years have you interacted with *Prosopis juliflora* plant (compare with Q.6 to get accurate time?

……
…..

(D) If your answer was yes in **Q.14.A**, When has *Prosopis juliflora* started to be invasive in the sub location?-(**Compare with Q.6 and 14 C)** to get the your time of choice)

……..

15. (A) Kindly answer if *Prosopis juliflora* (**Mitilaya** in Samburu language) has **negatively impacted** on your socio economic activities and **rate Impacts** according to your experience in the sub location as stated below (See Likert rating scale provided below)

Socio-Economic Activity Impacted	**Answer**		**Perceived Magnitude of Impacts**				
	Yes	**No**	**1 Insignificant**	**2 Minor**	**3 Moderate**	**4 Major**	**5 Severe**
Governance-grazing systems and rules							
Livestock production-yields, health, diseases, injuries, trapping							
Income and expenditure systems-sources, diversity, costs							
Local transport/Access to services-health, education, grazing fields							
Natural resource use conflicts/disputes							

Source: Screening checklist (Nackley *et al*., 2017), Likert rating scale adopted from (Williams, 2013)

(B) Based on you rating above, explain real impact scenarios or live experiencesfor each impact categories indicated below? You mar referto the above table for information to be considered in each of the below impacts!

Governance systems (Nkitoria in Samburu Language)

……

Livestock production

……Impact on household Income

……

Impact on household expenditure

……

Local transport/movement

……

Natural resource use conflicts/Disputes

……

(C) While living in the sub-location, has impacts of *Prosopis juliflora* (**Mitilaya** in Samburu language) changed your economic activities to earn a living or improve income? Yes No

(D) If **yes**, elaborate on the the economic activity or activities you have changed to?

……

(E) Give comment/s if the economic activities you have changed to in (**15, D**) above have improved your livelihood compared with your mainstay?

……

16. (A) Kindly answer if *Prosopis juliflora* (**Mitilaya** in Samburu language) has **negatively impacted** the environment of the Sub Location and **rate Impacts** according to your experience in the sub-location as provided below (See Likert rating scale provided below).

Component of the Environment Impacted	**Answer**		**Perceived Magnitude of Impacts**				
	Yes	**No**	**1 Insignificant**	**2 Minor**	**3 Moderate**	**4 Major**	**5 Severe**
Water availability							
Impacts toWildlife-numbers, diversity, health, habitats, injuries, trappings							
Land productivity(Soil erosion)							
Grasslands							
Natural regeneration of plants							

(B) Based on your above ratings, explain real impact scenarios or live experiences for each impact categories**?-make references to the above table for information to be considered in each of the below impact**s?

Impacts on water resources

……
……

Impacts on Wildlife

……..

Land productivity/Soil erosion impacts

……

Impacts on grasslands

……

Impacts on plants natural regeneration/recruitment potentials of other plants

……

17. **(A)** Have you derived benefits from theseplants in the Sub-Location?

Plant	Socialor Economic Benefits	Environmental Benefits	Remarks
Vachelia reficiens (Lchurai)			
Prosopis juliflora (Mitilaya)			
Other invasive			

(B) Which of these plants can you say is disastrous in the area?

Plant	**Yes**	**No**	Remarks
Vachelia reficiens			
Prosopis juliflora			
Other invasive (specify)			

18. (A) Have these invasive plants **caused any displacement or local extinctions of key plants or** wildlife (wild animals) in the Sub-Location?

Yes No

(B) If **No** go to **Q.19** and if **yes,** State plants (**herbs, grass, trees, and shrubs**) or wild animals **(wildlife**) displaced or **made locally extinct** by the plants in the Sub-Location according to the following conservation status!

Invasive Plant	**List locally extinct species caused by the listed invasive species**				
	Trees/Shrubs	**Browse plants**	**Grass**	**Wildlife (Wild Animals**	Remarks
Vachelia reficiens					
Prosopis juliflora					

19. **(A)** How have you observed the spread and distribution of these invasive plants for the last decade (10 years)?

Plant	Increasing	Decreasing	Fluctuates	Constant
Vachelia reficiens				
Prosopis juliflora				
Other invasive				

(B) State the probable cause of the spread/distribution pattern?

……
……

20. **(A**) in the sub-location, which areas have been taken over or heavily infested by the species?

Sites colonized or infested by *Vachelia reficiens*

……
……

Sites colonized or infested by *Prosopis juliflora*

……
……
…….

Sites colonized or infested by other invasive species

……
……..

21. Based on your perception of these species, do you wish they be eradicated or they can be managed to reduce their spread and impacts?

Species	Would wish to be eradicated	Would wish management not eradication
Vachelia reficiens		
Prosopis juliflora		
Other invasive species(Specify)		

22. Considering your interactions with *Vachelia reficiens* and *Prosopis juliflora*, do they grow together or exists in an area with other invasive species as in (**10, D**)? Elaborate your answer!

.....

SECTION D: MANAGEMENT INTERVENTIONS ON *VACHELIA REFICIENS* AND *PROSOPIS JULIFLORA* IN THE SUB LOCATION

23. (A) (i) are there any management interventions directed to *Vachelia reficiens* and *Prosopis juliflora* in the Sub-location*?*

Vachelia reficiens Yes No

Prosopis juliflora Yes No

(ii) If yes, elaborate on year and actors per species?

Plant	Actors/Implementer	Year
Vachelia reficiens		
Prosopis juliflora		

(B) (i) If **yes**, what are the control methods used and their efficacy?

		Effectiveness				
Species	Method/s of Control	Non effective	Less effective	Moderately Effective	Effective	Highly Effective
Vachelia reficiens						

Prosopis juliflora						

Source: Likert Scale, (Williams, 2013)

(ii) Which among the listed methods do you prefer as effective compared to the rest? Give reasons as to why you consider the method as effective?

(a) Method

……
……

(b) Reasons or explanations why it is effective

……
……

(iii) Do you agree that the interventions have been beneficial your;

(a) Socio-Economic activities

……
……

(b)The Environment

……
……

(iv) According to you, how can the most effective method/s be sustained or adopted?

……

(C) What are post management activities or treatments you practice to ensure the areas infested are reclaimed successfully to guarantee land productivity?

……

24. Apart from *Vachelia reficiens* and *Prosopis juliflora*, are there any interventions directed to other invasive species in the area?

Yes **No**

Explain your answer by species?

……
……
……

25. (A) Have you ever participated in any management or control interventions on *Vachelia reficiens or Prosopis juliflora* OR other invasive plants*?*

Yes No

Explain

……

(B) What are some ofyour contributions on the management of the invasive species i.e. what costs have you incurred in cash or in kind including labour cost or voluntary work?

.....

26. **(A)** If you participated in the control of these species **(Acacia and prosopis**), at what stage (seedling, saplings or young tree, mature tree or at any stage of tree development) do you control these invasives?

	Stage of Control				
Species	Seedling	Immature tree	Mature tree	At any Stage	Remarks
Vachelia reficiens					
Prosopis juliflora					
Other invasive					

(B) Which time of the year or season are these species controlled? Tick your answer!

	Season of control in the year			
Species	Rainy Season	Dry Season	Any Time of the Year	Other specify
Vachelia reficiens				
Prosopis juliflora				
Other invasives				

27. Is there coordinated structure when controlling the plants? Explain your answer!

……

28. Which risksor challenges have you encountered while managing the invasive plants?

……

29. Are there any by-laws or resolutions on the management of these species in the sub-location? Account for your answer?

……

30. Based on your experiences in the Sub Location, have you noticed natural factors or enemies of the above mentioned invasive plants as in **Q.25** which you believe have controlled the abundance of these species in some areas?

(A)*Vachelia reficiens*……

(B)Prosopis juliflora

……

(C) Other invasive (Specify)

……

31. If this plants are not controlled, what could happen to you as a household?

Vachelia reficiens……

Prosopis juliflora……

32. According to you, what can be pursued to sustainably reduce the populations of invasive plant species in the Sub location?

.....

33. Share any information or experience you wish to share on these invasive species?

……

To this end, I thank you very much for actively participating in the interview. Your opinions will help us to understand perceptions and interactions on the impacts of invasive plant species in the sub-location and inform interventions for sustainable development. The results of this research will be communicated to you upon approval and publication of findings through the Samburu County Government communication channels, National Government and the media.

Ashe oleng

Thank you so much and be blessed.

FOCUS GROUP DISCUSSION GUIDE

Sub Location: …….. **Date: ……**

Venue GPS Location: Latitude……Longitude……

No. of Participants: ……..**Male: ……..Female**……**Abled differently**…….

FOCUS GROUP GUIDING QUESTIONS

1. Do you have plants you consider invasive in the Sub Location? If yes, identify and rank them in order of dominance!

2. Where have these species originated from and during what time or year have you considered them to be impacting negatively on your socio-economic activities and the environment you live in?

3. How have these plants affected you?-

(a) Socio-economically

(b) Environmentally

4. How have you acted or coped against the adverse impacts of the invasive species? Begin with the year of interventions!

5. What results have you had in the Sub Location from your actions?

6. Any special government/county/development partners interventions?

7. Any suggestion that would work to sustainably manage the invasive species in the Sub Location?

8. Do you have any comments on the invasive species you consider not captured in the above questions and that you would like to share with the group?

ASHE OLENG

THANK YOU SO MUC

H/ASANTENI SANA

KEY INFORMANT INTERVIEW GUIDE

Name of Respondent…….**Date**……...

Department/Section/Unit……

Other Categories: ……

Cell Phone No……Email Address:……

SECTION A. GENERAL INFORMATION ON SAMBURU EAST SUB COUNTY

1. (A) which economic activities are practiced in the Sub County?

……
……

(B) Which one do you consider as the mainstay of the inhabitants?

……
……

2. State major environmental issues or challenges of concern you have encountered while working or living in the Sub County and you believe to be key?

……
……

SECTION B. GENERAL INFORMATION ON INVASIVE PLANT SPECIES IN THE SUB COUNTY

3. (A) Are you aware of the meaning and existent of invasive plants? If so, kindly elaborate!

……
……

(B) On your experience, do you know of invasive plant species in Samburu East Sub County? If yes, list them and comment on their origin (**If indigenous or exotic**)?

……
……

4. What is the cause of their infestations or rate of spread?

……
……

5. For how long have these species been an issue in the sub county? State in years per the species?

……
……

6. From your experience has the abundance/number changed for the last 10 years?

Yes **No**

Explain your answer per species?

……
……

7. What could be the cause of the pattern as in **Q.6?**

……

8. Which **areas/sites** in the landscape of the Sub County have these species invaded mainly? List by species and sites invaded?

……

9. Are there **areas/sites** in the landscape where you do not like them to grow? List by species and the sites you don't like them to grow?

……

10. Give reasons as to why you do not like the species to grow in those particular **areas/sites** of the landscape of the Sub County? List by species and reasons for not liking them to grow in the mentioned sites?

……

11. (A) Explain some of the department's or Organization's priorities on invasive plant species and elaborate on plans and budgets in the Sub County? Provide Costing and explain your answer-**see Table below**?

……

Name of Organization	**Year**					**Proposed budget in Kshs or area to be restored**
	2017	**2018**	**2019**	**2020**	**2021**	**2022**
Gross expenditure (Kshs.)						
Hectares of land freed or claimed from invasives						

Total costs from 2006-2016 in kshs……

(B) State if the Department or Organization has undertaken a research or a survey on these invasive plants? Provide estimates of the costs in Ksh.

……
……

12. (A) Highlight **key** socio-economic impacts of the invasive species in the Sub County you know of? Explain your answer and specify socio-economic activities impacted negatively by invasive plant species?

.....
.....

(B) Are there environmental impacts of the invasive species in the Sub County you know of? Explain your answer and specify components of the environment impacted negatively? **Give any local extinction of plants or wildlife you know of?**

……
……

(C) Have the invasive species impacted negatively on our protected areas for instance;-Samburu game reserve, Mathew's Forest Ecosystem, wildlife orphanages, sanctuaries, conservancies and Ewaso Ngiro River etc.

……
……

13. Do these invasive plants have any benefits both environmental, social and economic you know of in the Sub County? List the benefits per species?

Environmental benefits per species

……
……

Social benefits per species

……
……

Economic benefits per species

……
……

SECTION C: MANAGEMENT INTERVENTIONS ON INVASIVE SPECIES IN SAMBURU EAST SUB COUNTY

14. Are there policy and legal frameworks for the management of invasive plant species at the County and National government level? If yes, highlight them!

……
……

15. Have the legislative guidelines been successful in as far as the community is concerned in relation to the invasive plant species?

……
……

16. Have the communities shown interest in managing the invasive species? Kindly elaborate on interests and investments/actions directed/innovations?

……
……

17. What is currently being done to eradicate or manage the species?

(A) State key management/control activities?

……
……

(B)Methods used to control the species?

……
……

(C) Comment on effectiveness of the methods used and justify your answer?

……
……

(D) Any innovation worth replication

……
……

(E)Are there capacity building activities to alert residents on risks of these invasive plants? Kindly explain and estimate costs incurred!

……
……

18. On control methods of ***Acacia reficiens*** and ***Prosopis juliflora*** what stage of the plant are these control methods applied e.g., at seedling stage, immature tree or mature tree or any stage? Choose the main stage by ticking?

	Recommended Stage of growth of Control				
Species	Seedling	Immature Tree	Mature Tree	At Any Stage	Remarks

19. (A) during what time of the year or season are these control methods of ***Acacia reficiens*** and ***Prosopis juliflora*** undertaken to manage the plant?-tick your answer!

	Season of the Year Control is done				Remarks
Plant Species	Rainy/wet Season	Dry Season	Any Time of the Year	Other (specify)	

21. counting on previous and current interventions are there successful intervention worth a replication? Explain your answer and include hectarage and strategies applied to realize the benefits?

……
……

22. State key grass species used to reseed targeted areas?

……
……

23. Have the interventions come with any risks/accidents/issues/challenges which could affect those involved in the interventions particularly aimed at controlling the invasives plants?

……
……

24. On actions or interventions, are there protocols or safeguards developed and observed on control methods of choice?

.....
.....

25. Based on your experiences and interactions on these species, are there natural factors or enemies which have been observed/known to check the numbers of these species? Explain per species and give examples!

……
……
……

26. Highlight post management activities for areas cleared of the invasive species?

.....
.....

27. What are some of the challenges experienced in sustaining reclamation of these areas infested by the invasive species after clearing?

……
……

28. What recommendations could you give to guarantee sustainable management of invasive species in the Sub County?

……
……
……

Ashe oleng

Thank you so much and be blessed.

Appendix III

Composition of the Members of Key Informants Interviews

No.	KII Name	Type	Mandate	History on Invasive Plant Species
1.	Kenya Wildlife Service	Public	Wildlife conservation and management	Awareness creation, eradication
2.	Kenya Forest Service	Public	Forest Conservation and management	Education, eradication
3.	Samburu County Government	Public	Environmental management	Policy development,awareness,eradication programmes
4.	Grevy's Zebra Trust	NGO	Rangeland management, conservation of the endangered Grevy's zebra	Runs community awareness programmes, invasive species eradication activities
5.	ACTED	NGO	Rangeland management and restoration	Eradication activities
6.	CODES	CBO	Rangeland restorations	Eradication activities
7.	County Environment Committee Member	Community representative (pastoralist	Advocates for integration of environmental concerns among pastoralists	Awareness creation, eradication activities
8.	West gate conservancy Chairperson	CBO	Wildlife conservation rangeland management,	Rangeland restoration, eradication
9.	Ngutuk E Ngiron conservancy	CBO	Wildlife conservation, rangeland management	Wildlife management, eradication activities
10.	Kalama community conservancy	CBO	Wildlife conservation, rangeland management	Wildlife management, eradication activities

APPENDIX IV

HOUSEHOLD HEADS INTERVIEW AND FOCUS GROUP DISCUSSIONS SCHEDULE

	Interview Dates	Locations	Sub Locations (USUs)	No. of Respondents	Focus Group Discussions
	08-09 /06/2022	Lodung'okwe	Lengei	4	
			Lpus	4	
			Ltirimin	4	
			Sesia	8	x
	10/06/2022	Ngilai Central	Ngilai Central	16	
	11/06/2022	Ngilai West	Lkisin	9	
	13-14/06/2022	Waso West	Lengusaka	3	
		Waso West	Remote	4	
	15-16/06/2022	Wamba	Matakwani	11	
			Wamba	27	
			Golgoltim	9	
	17/06/2022	Waso West	Ngutuk Engiron	3	
			Lpus Leluai	8	
	18/06/2022	Waso West	Lerata	3	x
	22-24/06/2022	Sereolipi	Donyo Wasin	15	
			Sereolipi	10	x
Total	**12 Days**	6	16	138	3

X-Randomly selected Sub Locations for the Focus Group Discussions

APPENDIX V

LIKERT SCALE FOR IMPACT ASSESSMENT

	Perceived Magnitude of Impacts						
Attributes	0 No impact	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Severe	Horizontal Means

APPENDIX VI

PARTICIPANTS' PRIOR INFORMED CONSENT FORM

Introduction: I am……a master's of science student at Maasai Mara University, Narok, Kenya.

Interview Objectives: The purpose of the interview is to get an understanding of the impacts of *Vachelia reficiens* and *Prosopis juliflora* on Socio-economic and environmental in Samburu East Sub-County. The study further, aims at understanding management interventions directed to this species whose presence in the sub-county has elicited concerns on their possible impacts which may be undesirable. To this end, the study also aims to know if there are any management interventions directed to the species. In particular, the study aims to identify the effectiveness of the methods of control of these species.

Acknowledgement: Thank you for agreeing to participate in this study, which will take place in the month of June and July, 2022 in your respective sub-location.

Participants Rights: During the interviews each and every one of you has a right as a participant including the right to be heard and withdraw from the interview. The proceedings will be photographed and tape recorded using a smart phone subject to you agreeing. **Benefits of the Study**: Your active participation in terms of raising questions or any matter as the interview proceeds will assist in the attainment of the above research objectives whose outcome will be a thesis. The thesis will identify the concerns of the species, inform decision and policy makers on the impacts of the species and their sustainable management to spur environment sustainability and economic advancement in the Sub-County. Both the National and Samburu County Government are aware and have approved this very important study for the county.

Anonymity: The auto taped information and images of the study may be played or reproduced in the course of the study. However, participants' names and any identifying information will be kept anonymous and confidential.

I certify that I ……agree to the terms of the interview agreements.

Signature……...Date……..…

APPENDIX VII
LIST of PLATES

18/6/2022

Plate 3: FGD at Lerata sub-location under *Vachelia reficiens* shade

Plate 4: Management interventions of *Vachelia reficiens*-method of cutting at mid-height (Lerata sub-location)

17/6/2022

Plate 5: Utilization of *Vachelia reficiens* in fencing (Remote sub-location).

Plate 6: Impact of *Prosopis juliflora* on riparian ecosystems-displacement of riparian species. Arrow points to a *Vachelia tortilis* sapling choked to drying point by *Prosopis juliflora* (River Sereolipi).

Photography on participant prior informed consent by;

Patrick P. Lekenit
Assisted by;
Richard Lemarkat-Research Assistant
Harry Saoli-Resaerch Driver