CONTROLLING P. juliflora THROUGH SUSTAINABLE LAND MANAGEMENT: THE DETERMINANTS OF LAND USERS' DECISIONS AND PRACTICES IN MARIGAT SUB-COUNTY, KENYA.

BY

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DECLARATION

I declare that this research is my original work and has not been submitted for examination or award of degree in any other institution of higher learning. Other people's work used in this research has been properly acknowledged and referenced in accordance with the University of Nairobi requirements.

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DEDICATION

I dedicate this thesis to my spouse, Phonfred Jaoko, and my sons Derick Mich, David Hikari, and Dylan Wagen, whose boundless love and encouragement provided the solid ground upon which I stood throughout this academic journey.

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ASALs	Arid and Semi-Arid Lands
DMCE	Deliberative Multi-criteria Evaluation
FAO	Food and Agricultural Organization
FGDs	Focus Group Discussions
GoK	Government of Kenya
IAS	Invasive Alien Species
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
KNBS	Kenya National Bureau of Statistics
LULC	Land Use and Land Cover
MEA	Millennium Ecosystem Assessment
SDG	Sustainable Development Goals
SLM	Sustainable Land Managements
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UN-HABITAT	United Nations Human Settlements Programme
WOCAT	World Overview on Conservation Approaches and Technologies
WRI	World Resources Institute

ABSTRACT

The effective implementation of sustainable land management (SLM) practices is vital for achieving land degradation neutrality. However, the sustainability of these practices depends on the continuous decisions made by land users to adopt and implement them. Unlike studies on other forms of degradation like desertification and soil erosion, there is a lack of focus on Invasive Alien Species (IAS) management in studies related to SLM uptake and implementation. Consequently, applying the findings of SLM studies to invasion management remains uncertain due to the complex nature of the invasion process. This study aimed at: 1) analyzing the potential of stakeholder-led participation in contributing to the effective selection and sustained use of SLM practices to manage *P. juliflora*, 2) analyzing spatio-temporal invasion trajectories of *P. juliflora* cover and relating their spatial occurrence to relevant landscape features, 3) evaluating drivers influencing land users' decisions for SLM implementation, and 4) assessing land tenure right barriers that impact land users' implementation of SLM practices. Conducted in Marigat Sub-County, land cover data collected from 1988 to 2016 were analyzed to generate spatio-temporal trajectories related to landscape features, while 150 respondents from both the heavily and sparsely invaded areas were interviewed. The study observed that participation in a structured decision-making process enhances stakeholders' knowledge of the significance of invasion, prompting them to prioritize the need to manage IAS. A notable distinction ($p<0.05$) in perceptions emerged between engaged local implementation groups (LIG) and non-LIG members regarding the imperative need to manage the invasion. Further, 89% of LIG members either agreed or strongly agreed on the necessity to control the proliferation of *P. juliflora*. The spatio-temporal analysis of *P. juliflora* trajectories revealed that the trends of invasion is correlated ($p<0.01$) with underlying land management decisions and drivers, rather than a random occurrence. The ongoing management of *P. juliflora* dominates on few, small parcels where land users anticipate a substantial threat of invasion to their income or potential costs if left unmanaged. Consistently cleared parcels accounted for a mere 110 hectares (2% of the study area), with only 7 hectares (Ha) experiencing long-term clearance. This low and declining cover of cleared areas indicates the unsustainability of existing management options for long-term invasion control. In contrast, the consistently invaded parcels were highly prevalent, and with an increasing trend covering 6,329 hectares (94% of all trajectory categories), mainly distributed within 800 meters from roads. Further, communally shared parcels such as pasturelands and roadsides are the most vulnerable, yet the most neglected in terms of invasion management. This is because there's a perception that no one is held accountable, especially when economic benefits aren't guaranteed for land users. Additionally, the study identified critical tenure right barriers within the customary tenure system, namely the partriarchal system, dysfunctional enforcement institutions, unresponsiveness of tenure rights to livelihood changes, and limited land transactions that leaves vulnerable parcels under the ownership of the elderly community members who lack capacity to manage invasion. The study underscores the importance of economic benefits as an incentive to land users' their collective participation in invasion management at the landscape level. Trajectory

IAS mapping was also found to be important planning tool to enhance the prioritization of context-specific and timely response mechanisms. As a key recommendation, the study advocates for the national IAS management strategy to focus on empowering grassroots-level actors in addressing challenges to Sustainable Land Management (SLM) implementation, especially concerning IAS management at the landscape scale.

CHAPTER ONE: INTRODUCTION

1.1. Background of the study.

1.1.1. P. juliflora invasion as a form of land degradation

One of the critical human-induced drivers of global environmental degradation, which is associated with substantial social, ecological, and economic impacts, is the invasion by alien species. According to Shackleton *et al.* (2014), invasive alien species (IAS) refer to species that have been introduced, either intentionally or unintentionally, into areas outside their native ranges. Once established, these species spread and have negative impacts on the local ecosystems. *Prosopis juliflora* (Sw.) DC. (hereafter referred to as *P. juliflora*) is listed as one of the 20 most dreaded invasive woody weeds in Australia, South Africa, Ethiopia, Kenya, and Sudan (Mwangi & Swallow, 2008, van Wilgen, *et al.,* 2012, Wise *et al.,* 2012). It is an evergreen, fast-growing, and nitrogen-fixing woody plant which is tolerant to saline and dry areas. The species has deep roots penetrating to a depth between 15-50 m and is allelopathic (Canadell *et al.,* 1996). *P. juliflora,* originally native to the Caribbean and South and Central America, has been introduced to regions beyond its native range due to the perceived benefits it offers such as a source of fodder, soil conservation, fuelwood, construction materials, and for the rehabilitation of degraded lands (Shackleton *et al.,* 2015, Mwangi & Swallow, 2008).

While introducing *P. juliflora* was initially associated with social, economic, and environmental benefits, its invasion negatively impacts biodiversity, ecosystem services, and livelihoods, especially among vulnerable rangeland communities. In South Africa, *Prosopis spp* was introduced with the purpose of providing shade and fodder. Still, it encroached and invaded grazing fields and water access points, especially along floodplains, to the extent that exceeded the financial capacity of a public works program to restore (Wise *et al.,* 2012). The findings of Wise *et al.*, (2012) projected that if the status quo is maintained with no successful implementation of sustainable management measures, invasion densities may reach a level where their water uptake balances the rainwater, thus hindering lateral water drainage to the ground.

In Baringo Kenya, *P. juliflora* is a key driver for land degradation as depicted in its encroachment of grasslands and croplands (Mbaabu *et al.*, 2019b) . Likewise, *P. juliflora* depletes underground water making them unavailable to other native plants. According to Shiferaw *et al.* (2021), an individual *P. juliflora* tree has a daily average water consumption of 7 liters. This level of groundwater uptake translates to an annual *P. juliflora* water consumption of 3 billion m^3 in the Afar region, Ethiopia. The projected yearly water intake by *Prosopis* is thus sufficient to irrigate 330 000 ha of sugarcane, the main cash crop in the Afar region. In another study, *P. juliflora* had invaded approximately 1 million ha in Ethiopia, with significant losses of natural riverine forests, grasslands, and woodlands, as well as providing evidence that it can be the most critical driver of land use and land cover (LULC) changes at a regional scale (Shiferaw *et al.,* 2020). As stated by Linders *et al.* (2019), the presence of *P. juliflora* in Marigat, Kenya, negatively affects ecosystem functioning, leading to a decline in native species when the cover of *P. juliflora* exceeds 40%. Furthermore, *P. juliflora* poses physical risks to humans and livestock due to its thorns, and it can also serve as a hiding place for criminals, thus posing a security threat (Maundu *et al.*, 2009; Mwangi & Swallow, 2008).

1.1.2. Management of P. juliflora invasion

The adverse impacts of invasive alien species (IAS)s on ecosystem services and local livelihoods have triggered widespread interest in management approaches. Several studies (Anderson, 2005; Mwangi & Swallow, 2008; Zachariades *et al.,* 2011) have proposed mechanical removal, chemical treatment, biological control, and control through utilization as management options in most invaded countries. However, implementing management practices has been unsuccessful in sustainably managing the spread of IAS such as *P. juliflora,* especially in developing countries. Individual land users' management decisions have been prompted by their attempt to change to more desirable land uses in response to various underlying drivers; socioeconomic, environmental, or political factors (Briassoulis, 2017). Such management decisions often lead to different patterns of *P. juliflora* as individual land management actions cumulatively translate to large-scale land cover changes (Briassoulis, 2017). This calls for integrating management options into sustainable land management strategies to manage invasion effectively. However, sustainable management of invasive species is only possible if the implication of land users' management decisions to invasion patterns are established and drivers for such land management decisions addressed.

1.1.3. Sustainable land management as a potential solution

Recent studies have highlighted the critical need for sustainable management of the *P. juliflora* invasion due to its continuous expansion in cover and negative consequences on ecosystems and human well-being (Mbaabu *et al.,* 2019; Shiferaw *et al.,* 2019). Like in other forms of degradation, implementing sustainable management (SLM) practices is crucial in sustainably managing IAS's spread and negative impacts (Schwilch *et al.,* 2012). Sustainable Land Management (SLM) involves the rational utilization of land and its resources to generate goods and services that improve human livelihoods while ensuring the long-term preservation of its productive capacity and environmental functions (Alemu, 2016).

According to Schwilch *et al.* (2012), SLM presents a solution to many environmental disturbances, including invasive species control, biodiversity loss, climate change, land degradation, and food insecurity. Apart from being a crucial component of sustainable development and poverty alleviation, the integration of SLM practices in managing invasive species enhances the sustainability of such management approaches. This is supported by Mwangi and Swallow (2008), who affirm that successful management of invasion impacts may not be attained unless management options are integrated into SLM strategies. However, unlike other forms of degradation such as deforestation, desertification, and soil erosion, invasive species are rarely in the limelight as a form of global land degradation. As a result, studies on SLM adoption and implementation tend to focus on addressing other forms of degradation, making their practical application to IAS management uncertain. This is despite the understanding that controlling IAS and mitigating their adverse impacts (SDG 15.8) aids in the reduction of other forms of degradation through the restoration of degraded lands (SDG 15.3) and the conservation of biodiversity (SDG 15.4).

1.1.4. Challenges to the successful implementation of SLM practices

Successful implementation of SLM practices is premised on a sense of ownership among land users. Schwilch *et al.* (2012) assert that although participatory approaches may not necessarily lead to better decisions in selecting SLM strategies, they are crucial in ensuring social acceptance and ownership of the established practices. The Community is likely to embrace SLM practices that are socially acceptable, economically viable, and ecologically friendly and address environmental challenges as perceived by the community. However, community decisions on implementing SLM practices are pegged on culturally defined institutions that shape community actions. However, there is a lack of traditional knowledge about dealing with new plant invaders, which may have unique species traits and respond differently to SLM practices than native trees. Therefore, effective institutional frameworks are a crucial element in ecosystem restoration due to their critical role in enforcing restoration measures. Likewise, an assessment of current institutional designs reveals that local and global institutional frameworks are not explicitly designed to manage common-pool resources, which is a critical element of the Millenium Environment Assessment (MEA, 2005). The same challenge is experienced during the restoration of invaded lands as IAS have no defined boundary hence the need for collective action in their management, enforced by an efficient institutional framework.

Regarding SLM practices aimed at controlling *P. juliflora*, issues of land tenure systems and related tenure rights are fundamental institutional aspects playing a significant role in the uptake and successful implementation of SLM practices.

Land tenure entails rules and policies that regulate and control all transactions in land hence central to attaining sustainable management of natural resources (Kasimbazi, 2017). The author posits that securing the tenure rights of land users enhances their implementation of SLM practices since they have limited restrictions on access and utilization of land resources.

Considering the divergent cover density and stage of invasion, management interventions should address an appropriate management goal; prevention, early detection, rapid response, and control of invasive species. Prevention is the most effective management strategy for invasive species as it aims to halt the establishment of IAS upon arrival. Prevention can be achieved through capacity building to create awareness, collaboration with partners to prevent the introduction and thus spread, as well as the implementation of preventive measures such as sanitation of areas infested by IAS. When prevention is not successful in stopping the introduction and establishment of IAS, Early Detection and Rapid Response (EDRR) may be employed to locate and eliminate new infestations before they spread (Reaser *et al.*, 2020) . However, once IAS are established and widespread, management strategies would require their control to reduce their spread and mitigate their adverse impacts on the environment and ecosystem services (Epanchin-Niell *et al.*, 2010).

IAS spread rapidly over large areas and within short periods, thus impacting the entire community rather than an individual (Bierbaum *et al.,* 2018). Therefore, collective decisions to invest or not in the adoption and continued use of SLM practices determine the spatial patterns of IAS distribution (UNCCD, 2017;

UNCCD, 2019). This illustrates that management interventions should be addressed at the communal level. However, the whole process leading to land users' responsive actions is shaped by multi-dimensional drivers stemming from governance decisions, environmental conditions, and trends, as well as social and economic dynamics, all of which have a complex systemic interaction (Banadda, 2011; Wiesmann, 2012; Shackleton *et al.,* 2016). Consequently, knowledge of the drivers influencing land users' decisions to implement SLM practices at the communal level should be explored if sustainable management of IAS is to be achieved.

While several studies on SLM adoption and implementation exist (De Graaf *et al.,* 2008), most of them focus on soil and water management and target the adoption of SLM practices by single land users on isolated or individualized parcels of land. Transferring their findings and recommendations to IAS management may therefore be irrelevant. Based on the aforementioned invasion complexities, IAS management requires a spatially differentiated management strategy that builds from drivers influencing land users' collective management decisions. Therefore, while adopting SLM practices is vital in managing invasion, a coordinated approach that considers a systemic evaluation of spatially explicit drivers to actors' decisions in adopting SLM practices is an important aspect of invasion management. Similarly, exploring alternative methods that contextualize SLM adoption to IAS management should be examined to identify practical entry points that foster SLM uptake among land users.

1.2. Statement of research problem

SLM practices are widely acknowledged as potential solutions to many environmental problems, including IAS management. However, their ineffective implementation by land users limits their sustainability in managing invasive species. Despite the growing interest in promoting SLM implementation, SLM selection is often non-participatory, resulting into lack of ownership which hinders uptake and continued implementation (Saguye *et al.*, 2017). Consequently, *P. juliflora* presents a consistently increasing trend in Marigat (Mbaabu *et al.*, 2019) , with communally owned parcels being most susceptible to invasion. Further, despite the potentiality to spur collective management actions, the aspect of a participatory and structured decision-making approach in SLM selection by land users is new in *P. juliflora* management (Bagavathiannan *et al.*, 2019; Niemiec *et al.*, 2020) . Thus, it is necessary to evaluate its potential in selecting effective SLM practices that land users will be willing to implement continuously.

It is crucial to adopt a coordinated approach for invasion management, surpassing individual farm levels. However, in Marigat Sub-County, invasion management is predominantly implemented on individual farms, rather than at a landscape scale. This may be attributed to the lack of a shared knowledge on invasion trends and their relationship with management decisions (Bagavathiannan et al., 2019) . Existing bi-temporal invasion trend analyses (Dean *et al.*, 2002; Mbaabu *et al.*, 2019) lack spatial details over multiple timeframes, and there is no explicit attempt to link invasive species trajectories to land users' management decisions. This gap complicates the identification of drivers behind land users' decisions contributing to specific invasion patterns. The failure to correlate invasion trends to management decisions also makes it difficult to assign appropriate management options. As a result, selection of non-prioritized interventions that are unresponsive to local challenges hampers continued SLM implementation.

Land tenure is a critical institutional aspect in SLM implementation, providing guidelines on land access, utilization, and management. Poor enforcement of land tenure rights significantly contributes to the unsustainable implementation of SLM practices. In Marigat, where pastoralism and agropastoral livelihoods prevail, communal tenure systems dominate. Despite formal governance structures, communities heavily rely on informal customary rules. Harmonizing user rights between pastoralists and farmers is challenging, especially in reclaiming invaded lands through SLM practices. Customary regimes often limit women's ability to implement SLM on land they may not claim. Despite institutional frameworks like the Community Land Act (2016) and Land Registration Act (2012), existing tenure right barriers impede the intended mandate of enforcing tenure rights.

1.3. Research questions

This study, therefore, sought to understand the challenges facing the management of *P. juliflora* and propose appropriate solutions for the uptake and continued use of SLM practices. To achieve this, the study sought to answer the following research questions:

1. What is the role of stakeholder-led participatory processes in contributing to the effective selection and the chances of continued use of SLM practices to control *P. juliflora* invasion?

2. What are the spatial-temporal trends of *P. juliflora* trajectories and how is their occurrences related to land management decisions?

3. What are the drivers to land users' uptake and continued use of SLM practices to manage *P. juliflora* invasion?

4. What tenure rights barriers influence land users' implementation of SLM practices to manage the invasion of *P. juliflora*?

1.4. Objectives of the study

1.4.1. General objective

The study's main objective was to evaluate drivers of land users' management decisions as reflected in invasion trends and proposed entry points for continued implementation of SLM practices for managing *P. juliflora* – a highly invasive tree species in East Africa.

1.4.2 Specific objectives

In order to accomplish the overarching goal stated above, the study was guided by four specific objectives:

1. To evaluate the potential of stakeholder-led participatory processes in contributing to the effective selection and the chances of continued use of SLM practices to control *P. juliflora* invasion.

2. To analyze spatio-temporal invasion trajectories of *P. juliflora* cover and relate their spatial occurrence to land management decisions.

3. To evaluate the drivers influencing land users' adoption and continued utilization of sustainable land management (SLM) practices for the management of *P. juliflora* invasion.

4. To assess the tenure right barriers that influence land users' implementation of SLM practices to manage the invasion of *P. juliflora*.

1.5. Justification of the study

The results of this study have significant implications for policymaking as they provide empirical data that informs the sustainable management of invasive species. Additionally, the study suggests effective entry points for strengthening the collective adoption and ongoing utilization of sustainable land management (SLM) practices to effectively control the invasion of *P. juliflora*. Further, the study contributes to knowledge of the relation between spatio-temporal invasion trajectories and drivers of land users' decisions in managing invasion. This is instrumental in identifying priority areas for management and supports effective decision-making by providing evidence-based knowledge on drivers of different *P. juliflora* covers trajectories and how they influence future management options. Likewise, it informs reforms in policy guidelines based on empirical study findings related to land tenure rights enforcement that are useful for the successful implementation of SLM practices needed for *P. juliflora* management. The choice of Marigat Sub-County as the study area was based on its status as the most invaded sub-county, representing regions heavily affected by *P. juliflora* invasion in Baringo County. Additionally, the availability of data on the fractional cover of *P. juliflora* in Marigat facilitated the analysis of *P. juliflora* cover trajectories. Adapting the data for our analysis reduced duplication of work and minimized costs within our constrained budget.

1.6. Scope and limitation of the study

This study was limited to evaluating the role of the participatory process in the selection of SLM practices, the chances of their uptake and continued use, and the controlling effect of land tenure. It did not explore the implication of this process on actual uptake and the continued usage of SLMs, as these assessments entail observations over long-term periods that were far beyond the study time frames. Therefore, for this objective, we evaluated land users' opinions on whether they are willing to uptake and continually implement the practices. The evaluation of the selected SLM practices was constrained by their alignment with the three dimensions of sustainability: social acceptability, environmentally friendly, and economic viability, as perceived by land users. The selection of the three sustainability dimensions is based on the emphasis by Schwilch *et al.* (2012) that for an SLM to be sustainable, it has to meet the above three mentioned dimensions.

For the second objective, the study establishes a connection between invasion trajectories and land management decisions in Marigat sub-County. However, it focused on testing a planning tool for invasion management rather than explicitly defining spatially targeted invasion management decisions. Consequently, the spatial analysis was confined to enhancing the output of Land Use and Land

Cover (LULC) by developing trajectories specific to *P. juliflora* trends. Additionally, only variables proven to influence land users' management decisions of *P. juliflora* at the local scale, as observed in this study, were taken into account when analyzing the underlying spatial features associated with the trajectories. Therefore, rivers, roads, and irrigation schemes were the selected variables.

1.7. Operational definitions

1.7.1. Land tenure

Land tenure refers to the terms and conditions under which rights to land and land-based resources are acquired, retained, used, disposed of, or transmitted (Kenyan National Land Policy 2016). It is an institution that establishes conditions upon which land users can access, utilize, and manage land-based resources (FAO, 2002).

Land tenure can also be defined to demonstrate a direct relationship between people and land. According to UN-HABITAT (2008), land tenure refers to the processes that define how land is held or owned by individuals or groups, as dictated by legal or existing customary rules and regulations. It is, therefore, a tool for conservation as it consists of basic rules that guide how property rights are to be allocated within society (Kasimbazi, 2017). Land tenure can either be customary/communal, leasehold, freehold, or national/public tenure system.

Freehold tenure refers to where absolute rights of ownership are conferred to the landowner. There is, however, an exception where such rights can be withdrawn by the state in case the parcel needs to be appropriated for the sake of a shared public good, such as in the construction of public infrastructure. The public tenure system entails complete ownership of tenure rights by the state, which controls all land transactions. The community owns the land under the communal tenure system. Thus, tenure rights are assigned as defined by established customary laws, beliefs, and regulations. In the leasehold tenure system, the land is leased by the owning entity, either the state or an individual, through a contractual agreement. Such leases may either be over long or short periods. The standard leasing period of 99 years is usually considered to be as good as a freehold tenure system (Kasimbazi, 2017)

1.7.2. Land degradation

Land degradation is a phenomenon that systematically leads to the loss of biodiversity and the decline in ecosystem services in both terrestrial and associated aquatic ecosystems. It occurs in various forms ranging from desertification, soil erosion, deforestation, and invasion by alien species. The achievement of sustainable development goals requires the prevention, control, and reversal of land degradation. The promotion of sustainable land management practices can be facilitated through the provision of incentives that encourage their adoption (IPBES, 2018).

1.7.3. Sustainable land management.

Sustainable land management (SLM) is any activity aimed at rationally utilizing land and its related resources while conserving its productive potential for posterity (Alemu, 2016) . An SLM practice in this study refers to any physical activity aimed at attaining sustainable land management. In this study, we use the term 'SLM practice' to refer to any physical practice implemented on land to enhance the productivity of the land by controlling land degradation. According to World Overview on Conservation Approaches and Technologies (WOCAT), an SLM practice (also known as SLM technology) is any activity applied in the field, be it vegetative, agronomic, structure, or management measure aimed at enhancing land productivity and minimizing the impacts of land degradation.

Vegetative SLM practices involve planting vegetative matter, usually perennial trees, shrubs, or grasses over a long period to reduce the speed of water downslope, hence controlling soil erosion and its related forms of land degradation. Vegetative measures include windbreaks, agroforestry, afforestation, grass strips, and live fences. Agronomic practices are conservation measures that focus on reducing the impact of raindrops, increasing water infiltration into the soil, and reducing surface run-offs. Their implementation is often independent of the slope and is associated with annual crops planted on a rotational basis rather than for long periods.

Agronomic measures include mixed-cropping, intercropping, and mulching. Structural measures include gabions, check dams, retention ditches, and terraces constructed along contour lines or against prevailing wind direction to reduce wind velocity, surface run-offs, or soil erosion. In most cases, they require initial large investments and are constructed to last for long periods or permanently. Management measures involve a significant change in land use, often without including any agronomic or structural measure, intending to reduce intensity on land and enhance the vegetative cover. Management SLM practices include crop rotation, area enclosure, and change from forests to agroforestry.

1.7.4. P. juliflora

P. juliflora is an evergreen, deep-rooted, and thorny woody invasive species. It is drought tolerant and suitable for arid and semi-arid lands (ASALs) rehabilitation (Mwangi & Swallow, 2008). *P. juliflora* is the most widespread IAS in Kenya, attracting the most attention from policymakers, scientists, the public, and development agencies (Maundu, 2009) . This is because it adversely impacts ecosystem services due to its invasiveness, resistance, and poisonous nature (Geesing *et al.,* 2004).

1.7.5. Land cover trajectory

A land cover trajectory is a successive change of land cover over more than two time periods. Unlike bi-temporal detection of land cover, which is prominent in most studies, Spatio-temporal trajectories of land cover detect changes in land cover over long periods hence valuable for analyzing land cover trends rather than just the details of the transition between two successive time scales (Zhou *et al.,* 2007)

1.8. Thesis organization

The thesis comprises five chapters, with the first chapter presenting a background by succinctly reiterating the overarching aim and significance of the study. It establishes the context for a thorough exploration of the study's components, presenting the problem statement, study objectives, research questions, justification for the research, scope, and limitations, and concludes by defining operational terms used in the thesis.

In the second chapter, a review of relevant literature is conducted, identifying gaps addressed by this study. This section also introduces the theoretical and conceptual framework guiding data analysis, laying the groundwork for subsequent chapters.

Chapter three delivers a comprehensive overview of research methodologies, detailing the rigorous methods employed in sampling design, sample size selection, data sources, data analysis methods, and ethical considerations. Emphasis is placed on ensuring rigor and reliability in research execution.what about study area?

Chapter four is structured to present results and discussions per objective. Each objective's results are followed by discussions, interpreting and contextualizing findings within the broader academic landscape. The chapter progresses systematically through each objective by presenting results of objective one and discussing them before proceededing to the presentation of cbjective two results, followed by their discussion.

The final chapter summarizes key findings and derives recommendations from the study, providing a conclusive overview of the research journey.

CHAPTER TWO: LITERATURE REVIEW, THEORETICAL, AND CONCEPTUAL FRAMEWORK

2.1 Introduction

This chapter reviews the literature on the management of *P. juliflora* in light of participatory approaches to SLM selection and implementation, *the* importance of trajectory analysis in understanding drivers of land users' management decisions, and the role of land tenure rights in SLM implementation. Based on the highlighted body of knowledge, this chapter presents the identified research gaps that formed this study's basis. Finally, it explains the theoretical and conceptual frameworks that guided the implementation of this research.

2.1. P. juliflora as an invasive alien species

Biological diversity has intrinsic economic, socio-cultural, and ecological value to human well-being hence the need to conserve them to sustain life (UN, 1992) . However, the Millennium Ecosystem Assessment report revealed that the world species distribution is becoming more homogeneous due to the introduction of alien species outside their native ranges, leading to a decline of numerous native species (World Resource Institute. 2005) . This is because IAS, as their cover increases, encroaches and outcompetes native species.

Invasive alien species (IAS) are non-native species intentionally or accidentally introduced outside their native range, where they establish, spread, and become disastrous (Maundu, 2009) . They are a leading contributor to species endangerment and extinction after habitat loss and possess a worldwide economic loss exceeding US$ 300 billion annually (Luque *et al.*, 2014).

Among the world's worst invasive species, some of the most dominant invasive tree species are *Lantana camara, Senna siamea, Acacia mearnsii, Tithonia diversifolia, Psidium guajava, Opuntia stricta, some Eucalyptus species, and P. juliflora* (Clout & De Poorter, 2005; Hiwale, 2015; Rouget *et al.*, 2015; The National Invasive Species council, 2012). Compared with other common invasive alien trees and shrubs, none has manifested a fast and more widespread invasion in Arid and Semi-Arid Lands (ASALs) than *P. juliflora*. While the other species thrive better in humid and subhumid areas and highland areas, *P. juliflora* establishes and spreads in all altitudes and climatic conditions, making it easily adaptable to a range of topographical and climatic conditions. This makes it nearly the sole competitor with the native species (Maundu *et al.*, 2009).

In Kenya, *P. juliflora* is one of the most widespread invasive plants and a significant concern to policy makers, development agencies, and the government (Maundu *et al.*, 2009) . According to (Mbaabu *et al.*, 2019) , *P. juliflora* in Baringo County, Kenya has been progressively increasing at an annual rate of 640 ha, and the cover standing at 18,792 ha by 2016. *P. juliflora* is an evergreen, xerophytic plant native to the Caribbean, and south and Central America (Mwangi & Swallow, 2005). It was first introduced in Africa in 1822 through Senegal. It reached Kenya between 1982 and 1983 through the fuelwood and afforestation extension Projects to curb desertification and meet the high fuel wood shortage (Mwangi & Swallow, 2008).

While *P. juliflora* is associated with benefits such as a source of fodder, fuelwood, microclimate regulation in ASALs, soil conservation in degraded ecosystems, and shade provision (Mwangi & Swallow, 2008; Wakie, Laituri, *et al.*, 2016), it also poses adverse impacts on ecosystem services, livelihoods and biodiversity over time (Shackleton *et al.*, 2015; Wise *et al.*, 2012). Some of the adverse effects of the species are encroachment of agro-pastoral land, depletion of underground water, physical injury through their thorn pricks, and negative health impacts on both human beings and livestock (Shackleton *et al.,* 2015; Mwangi & Swallow, 2008). *Prosopis* is one of the top three invasive plants whose control has been prioritized in Ethiopia and is a declared noxious woody weed in Kenya and Ethiopia (Mwangi & Swallow, 2008).

2.2. Management of *P. juliflora*

The adverse impacts of IAS have prompted studies to control their spread. In the case of *P. juliflora*, decisions leading to the selection of management options have been subjected to conflicts of interest based on the benefits derived from the species (Mwangi & Swallow, 2008) . Existing management options are chemical, mechanical, biological, and cultural methods (Shackleton *et al.*, 2014) . Each management option has a set of benefits and limitations in controlling the spread of *P.*

juliflora. Chemical and mechanical control has been rated as the most effective yet expensive options (Wise *et al.*, 2012; Witt, 2010) estimated the cost of mechanical clearance on the North coast of South Africa to be US$ 13 ha^{-1} to US$ 534 ha^{-1} depending on the level of invasion. (Marais *et al.*, 2004) report that mechanical clearance costs often exceed the value of the land being cleared and thus are preferred in countries with low invasion levels and high financial capabilities (Shackleton *et al.,* 2014). Due to the high cost of implementing mechanical control, it has not been effective and hence unsuccessful in controlling *P. juliflora* spread especially where SLM practices are not integrated into post-clearance activities. This was demonstrated in South Africa where the *P. juliflora* invasion increased by 35% between 1996 and 2008 despite US$ 42.7 million being spent on mechanical clearance (Shackleton *et al.*, 2014)

In cases where chemical and mechanical control has failed, biological control has been recommended as an obvious solution to curtailing *P. juliflora* (Bagavathiannan *et al.*, 2019b; Zimmermann & Maennling, 2007). Biological control has the potential to cover large areas at minimal costs (Bagavathiannan *et al.*, 2019b; Shackleton *et al.*, 2014) and hence has been considered successful in controlling *P. juliflora* invasion in countries like Australia (Zachariades *et al.*, 2011) . Control through utilization has been the most contentious with some studies advocating for this method while others oppose it. While poor communities in most developing countries such as India and Kenya heavily rely on *P. juliflora* as a source of livelihood, there is no evidence of successful control of *P. juliflora* through utilization. In this regard, (Geesing *et al.*, 2004) believe that utilization encourages over-reliance on resources hindering management efforts.

Despite implementing various management interventions, the *Prosopis spp* invasion has not been successfully curtailed, as evidenced by an increasing trend of its cover in Africa. By 2010, 1.8 million hectares of South Africa were invaded with a projected annual rate of spread of 8% (Van den Berg, 2010). In Kenya, 1 million hectares have been invaded with a predicted potential to invade 35% of the Kenyan landmass, which was simulated by (Eckert *et al.*, 2020) to be suitable habitats for *P. juliflora.* According to Shackleton *et al. (*2014), *P. juliflora* spread will steadily increase unless more sustainable management options are adopted. However, management decisions are usually scientific-oriented and dominated by experts and scientists, limiting the chances of their further implementation by land users. In Baringo, management studies focused on clearance and requirements for clearing *P. juliflora* (Maundu *et al.,* 20019; Mwangi and Swallow, 2008). Thus, existing management options rarely integrate SLM practices and their role in sustainable invasion management.

2.3. Sustainable land management and *P. juliflora* management

Scientist, policymakers, and land users have intensified their interest in ecological restoration within the past few decades (Nilsson & Aradóttir, 2013). This is attributed to the growing awareness of the value of ecosystem services, pressure on world ecosystems, biodiversity loss, and the need to adapt to ecosystem changes (Cote *et al.*, 2021; World Resource Institute., 2005). SLM practices are perceived as one of the critical factors in the sustainable restoration of degraded ecosystems (UNCCD, 2017, 2019) . They are perceived to minimize the impacts of drivers to ecosystem degradation, such as climate change, land-use changes, and invasion by alien species, to mention a few (Nilsson & Aradóttir, 2013) , thus enhancing the resilience of disturbed ecosystems.

In the management of *P. juliflora,* the adoption of SLM practices has been greatly recommended for their spread to be sustainably curtailed (Adoyo *et al.* 2022; Anon n.d.; Mwangi and Swallow 2008) . This is because SLM implementation ensures that the restored land is not left idle for re-invasion by *P. juliflora.* However, SLM practices that are technically appropriate for one area may not be the best option for a different location. This is because they fall within different sociocultural, political, and economic contexts as well as face various ecological constraints (Sanz *et al.*, 2017).

The lack of a baseline survey, usually dependent on the availability of baseline information on socio-cultural, economic, ecological, and political factors, is a barrier to selecting appropriate SLM practice. Other obstacles to SLM implementation are reported to lack access to proper technology, information on SLM options and their implementation, lack of enabling institutional frameworks, and limited capital and financial resources (Sanz *et al.*, 2017) . In particular, economic considerations are one of the key motivations for land users in selecting and implementing SLM practices. This, however, creates a dependency on external subsidies and financial aid in implementing SLM practices, a failure of which continued implementation of SLMs may be discontinued.

Decisions on ecosystem restoration measures are firmly embedded in negotiation among stakeholders with varying preferences and tradeoffs that need to be considered in selecting and implementing SLM practices to enhance their effectiveness (Nilsson & Aradóttir, 2013). This was substantiated by studies integrating SLM practices on rangeland restoration in the Northern regions of the world (Denmark, Finland, Iceland, Norway, and Sweden), which asserted the need for an efficient participatory process of stakeholders to improve their commitment and realize positive results (Nilsson & Aradóttir, 2013).

The success in invasion management is also premised on whether selected SLM strategies are likely to be adopted by land users and sustainably implemented to meet their intended objectives. While SLM practices are applauded for their potential to restore degraded lands, most studies related to SLM adoption (de Graaff *et al.*, 2008; Saguye, 2017; Sietz & Van Dijk, 2015a) focus on soil and water management. Therefore, their findings on drivers to adoption might not be replicated in invasive species management. This is due to the invasion process's complex nature, which calls for a context-specific management approach.

2.4. Role of land tenure security on implementation of SLM

Secure land tenure has been widely acknowledged as key to supporting sustainable development by increasing access to land for vulnerable populations and empowering them to engage in SLM practices (Acts, 2003; Kasimbazi, 2017; Peters, 2009). According to (Kasimbazi, 2017), tenure security is the one of the key decisive factors as to whether landowners will engage in SLM practices. Secure land tenure is essential in mitigating land degradation, addressing gender imbalance, enhancing poverty eradication, and creating sustainable livelihoods (Acts, 2003; FAO *et al.*, 2002; Kasimbazi, 2017).

According to FAO (2002), indicators for insecure tenure systems have been highlighted as environmental degradation, the gender-based power imbalance in access to land, conflicts due to land disputes, and related human displacements or migration (FAO, 2002) . In this regard, the domination of patriarchal systems in African countries has seen women assigned secondary rights to land through their spouses, whose demise often exposes women to tenure insecurity, conflicts, and displacement (Wily, 2012).

Despite the significance of tenure security being acknowledged, determinants of security in land tenure are debatable, ranging from formal titling of land (Kasimbazi, 2017) to long-term tenure rights suitable for long-term investments (FAO, 2002) . This aspect of land titling has informed several land reforms in developed and developing countries, as seen in Mexico's 1992 major land reform which aimed to enhance tenure security through individual land titling. However, land titling is greatly contested by Cousins (2009)) and Wily (2017), who maintain that individual titling does not necessarily translate to secured land rights. Their arguments are supported by Bruce & Migot-Adholla (1994) 's conclusion that the only measure of tenure security is the communal recognition of an individual's rights to land. This is relevant to *P. juliflora* management, whose spread considers no boundary, and a collective effort in curtailing its spread is critical.

A previous finding (Arko-Adjei, 2011) concluded that titling does not create this social recognition and acceptance, which is naturally occurring in customary systems. Likewise, land titling leads to marginalization as the accessibility of land is limited to the few rich and powerful people who can afford such rights (Benjaminsen *et al.,* 2009). These arguments inform the notion that formal recognition and protection of the customary tenure regime and titling of communal land will translate to more secure tenure rights than private individualization and titling (Kasimbazi, 2017; Wily, 2018). This is confirmed by (FAO *et al.*, 2002) who maintain that individual land titling in existing regulatory frameworks is biased against secondary right holders like women who mainly access land through their spouses as dependants.

Therefore, the de jure existence of tenure rights does not necessarily mean those right holders will automatically access them. This is more practical in customary tenure systems where vital ecosystems like communal grazing land are degraded due to ineffective institutional enforcement of individual rights within the communal tenure regime. In some instances, this has encouraged biases in access, utilization, and allocation of benefits from communally owned resources, which discouraged collective action in communal resource management (Yami *et al.,* 2011). Enforcing tenure rights to make them accessible to land users is therefore crucial in promoting their involvement in the successful implementation of SLM practices. However, barriers limiting the successful enforcement of tenure rights have not been adequately identified and addressed.

A customary tenure regime is a system where land is owned by the indigenous community and managed by locally established customary institutions as defined by traditional cultural laws, with access to land rights being restricted to one's legitimate societal belonging (Bassett, 2007; Kasimbazi, 2017) . Customary land rights are complex, overlapping, and consist of both individual and group rights, complicating the jurisdiction under which they fall. This is because while the community legally owns the land, a huge chunk is often claimed by individuals who have privatized their rights (Greiner, 2016).

The forms and objectives of land reform have, however, been evolving with time depending on changing human needs. While the main focus of land reforms in the 19th century was redistributive reforms aimed at transferring land rights from large landholders to the landless, current reforms tend to concentrate on enhancing tenure security, ensuring efficient land administration, and supporting community-led land reforms (Sikor & Muller, 2009; Bassett, 2007) . Customary tenure systems, being the main targets of land reforms, have maintained their effectiveness over time but not without transitional changes (Cotula, 2007). The spectrum of rights related to land has transitioned from collective to individualized tenure systems, thereby reducing the legitimacy of customary institutions and contributing to the erosion of cultural values associated with land. (Arko-Adjei, 2011).

According to Alden Willy (2003), the main drivers of land tenure reforms are social and political transitions as countries seek to comply with internationally binding agreements related to fundamental human rights by strengthening democratization and devolution strategies. This places politics as the vital aspect determining changes in land tenure. Land tenure is believed to be a multi-dimensional aspect whose transformation is shaped by various factors encompassing social, economic, environmental, legal, and political facets (FAO, 2002) . Furthermore, Arko-Adjei (2009) has shown that demographic growth, urbanization, and commercialization of land are the main factors shaping transitions in tenure systems as land becomes commoditized to meet its high demand.

The primary distinctive and yet confusing forms of tenure systems are private and customary or often called communal tenure systems. Customary tenure, also called the customary tenure system, involves land administration managed explicitly by local and culturally structured institutions (Bassett, 2007). On the other hand, a Private tenure system is where absolute land rights are conferred to an individual, usually protected through land titling.

The dominant preference for private over customary tenure system is often based on the argument that group rights often override individual rights (Alden, 2003). Those advocating for the customary tenure system often assume that customary tenure indicates the absence of private rights (Peters, 2009) thus exposing individuals to insecure land rights, inaccessible credit facilities, and ineffective dispute resolutions that restrict their involvement in land-related investments (Arko-Adjei, 2011) . However, Bassett (2007) objects to this position and maintains that individual rights are explicitly considered within collective community rights. According to Arko-Adjei (2009), private land ownership is more insecure, especially for secondary right holders who may lack access to land in the case of individual land titling (Bouquet, 2009). This creates more disincentives that discourage investment in land (Peters, 2009). Furthermore, land reforms targeting land titling in African countries have failed to achieve their intended objective of enhancing tenure security and investment in land (Peters, 2009; Sikor & Muller, 2009). This indicates that the privatization of land through titling has no direct correlation with access to credit (Arko-Adjei, 2009).

Despite debates on the level of tenure security derived from private and communal systems, communal tenure regimes consistently dominate despite state attempts to phase them out (CISDL, 2003 Alden Wily, 2003). This reality has forced many African countries to officially recognize customary tenure as a statutory defined tenure regime (Wily, 2012) and decentralize land administration to communally based institutions. However, the question that needs to be addressed is the effectiveness and capacity of established customary land institutions in enforcing the complex and overlapping tenure rights associated with customary tenure regimes. Likewise, the local institutional ability to oversee a flawless titling process and establish and maintain a cadastre register has been questioned (Bouquet, 2009) . Again, the implication of customary tenure evolution on communal management of communally owned land remains unclear.

To address challenges within various land tenure systems, several legal frameworks have been instituted. The Land Registration Act (2012) advocates for the efficient and transparent registration of land titles, highlighting the necessity for an updated and cohesive land register (GoK, 2012) . These initiatives aim to facilitate conflict resolution related to land and improve access to tenure rights. Simultaneously, the Community Land Act (2016) stands as a crucial legal instrument formulated to address the complexities associated with communal tenure systems in Kenya (Community Land Act, 2016; Wily, 2018) . This Act empowers local communities to actively participate in decision-making concerning land allocation, acquisition, planning, and management through the establishment of Land Management Committees. It is anticipated that the Community Land Act will enhance participation, foster responsible governance, and promote environmental conservation (Wily, 2018).

While these legislative instruments underscore community participation, secure land tenure, and the recognition of communal land rights to create a conducive environment for responsible land use and conservation, the reality suggests that barriers to tenure rights persist, especially in communal lands, despite efforts to address challenges in accessing these rights. In practice, community members often resort to customary systems regarding land governance aspects. Therefore, it is imperative to examine the barriers presented by prevailing tenure systems and how they hinder the implementation of Sustainable Land Management (SLM).

2.5. Contribution of local actors' participation in environmental management

Attaining sustainable land management is dependent on the commitment of local actors who are agents of change. This is because their values and beliefs determine their participation in implementing SLM practices (Wiesmann *et al.,* 2011). According to UNCCD (2019), local actors' decisions to invest or not in adopting and continued use of SLM practices are significant in achieving neutrality in land degradation.

In managing invasive species, management strategies may be contentious primarily when land users who benefit from the invasive species differ from those who incur associated costs. The awareness of stakeholders' beliefs about an invasive species assists in developing a shared objective for management which enhances ownership of decisions related to management options. Thus, the participatory involvement of stakeholders affected by invasive species in invasion management is crucial in ensuring sustainable management. (Novoa *et al.*, 2018). Unfortunately, the integration of local actors in invasion management remains ineffective due to a lack of collaboration and support among local actors and land users. In particular, the effective participation of land users in invasive species management is hindered by a lack of reliable information on the impacts of invasive species and the benefits of their timely and sustainable management (Luque *et al.*, 2014). Further, land users are considered to implement practices from which they are likely to benefit (Epanchin-Niell *et al.*, 2010) . In the case of invasion management, high but immediate investments often yield benefits only in the long term. This advances uncertainties on the possibility of recovering investments in management practices and discourages land users' prioritization of engaging in management efforts.

The need to effectively integrate local land users' participation in sustainable land management is widely acknowledged, leading to the formulation of frameworks for the participatory integration of stakeholders in land management (Schwilch *et al.*, 2012) . Both studies emphasize the significance of engaging stakeholders in jointly formulating management goals and strategies to enhance ownership of management decisions. Likewise, they highlight the need to empower stakeholders by providing relevant information to inform their decision-making. Despite such efforts, to the best of our knowledge, no study has been conducted to test whether such comprehensive integration of stakeholders in land management increases their chances of implementing SLM practices. In particular, limited attention has been focused on relating land users' SLM implementation to managing invasive species, which are significant causes of land degradation.

2.6. Trajectories and drivers of land cover change

Trajectories of land cover changes have been defined as a successive progression in land cover changes observed in more than two temporal timeframes (Zhou *et al.*, 2008). It involves an assessment of a multi-temporal trend in land cover on a pixel-by-pixel basis. The historical evaluation of land cover changes is specifically useful in assessing the impacts of various drivers on land cover and land uses over long periods, often attributed to local, regional, variable environmental changes, political, and socio-economic drivers (Hernández *et al.*, 2016).

Drivers to land cover change are broadly categorized as either natural or anthropogenic, the latter being considered the most influential in shaping changes on land (UNCCD, 2017) . A recent advance that studied landscape change trajectories reported dominant changes in land cover to a more heterogeneous landscape, associated with anthropogenic activities such as farming, settlement, and deforestation (Hernandez *et al.,* 2016). However, both natural and human-induced drivers are interlinked and influenced by other indirect socio-cultural, environmental, economic, and political factors (Briassoulis, 2017). Environmental factors are biophysical aspects that determine how land is used, including climatic variability, land cover, and topography (UNCCD, 2012) . On the other hand, social factors are interventions that stakeholders execute through their democratic rights to protect ecosystems and improve human well-being (World Resource Institute., 2005). They include policies on resource utilization and management, education and communication, empowerment of vulnerable groups affected by ecosystem degradation, land users' beliefs, attitudes, demographic factors, and tenure systems (Briassoulis, 2017).

Finally, economic factors are those that influence the demand for and management of land resources, often determined by the profits anticipated from the choice of use to which land is put (Briassoulis, 2016; UNCCD; FAO., 2017; World Resource Institute., 2005) . However, economic and social-cultural factors are influenced by political decisions governing land-use policies. These may be in the form of state support through subsidies, tax exemption, and enforcement of policies that may influence land use and management.

Several studies (Del-Val *et al.*, 2015; Shiferaw *et al.*, 2019) have contributed valuable knowledge on the spread of invasive species and their associated drivers. The findings of the studies have highlighted anthropogenic disturbance, species richness, biophysical conditions, and availability of vegetative structures as the main drivers explaining invasive species distribution (Del-Val *et al.*, 2015) . A recent study in Ethiopia concluded that proximity to linear landscape structures such as roads and rivers had more significant explanations for the current distribution of *P. juliflora* compared to biophysical factors such as climate and topography (Shiferaw *et al.*, 2019) . They, however, acknowledge the need to exhaustively explore the contribution of other factors such as livestock migration patterns to invasion. These findings are consistent with those of Del-Val, *et al.,* (2014) who explain that roads, human settlements, and wetlands are associated with habitat destruction and anthropogenic disturbances and act as critical pathways for invasive species dispersal.

Trajectories of IAS cover, such as *P. juliflora, indicate* management decisions, as *P. juliflora* does not disappear naturally once it has been established. However, studies relating invasive species cover trajectories to their corresponding drivers are limited, making it difficult to inform management decisions based on drivers to cover trajectories (Zhou & Kurban, 2008). Understanding relevant socio-economic, political, and environmental drivers to *P. juliflora* trajectories is therefore crucial in supporting better decisions on *P. juliflora* invasion management. Previous studies on the subject (De Graaf *et al.,* 2008; Sietz and Dijk, 2015, Saguye, 2017) adopted surveys, meta-data analyses, and statistical methodologies to explain the drivers of sustainable land management. These approaches are limited in explaining causal relationships among drivers that shape land cover trajectories (Sietz & Van Dijk, 2015) . Combining such methodologies with spatially analyzed satellite imagery makes it easier to identify relevant trajectories of invasion and link them to their associated drivers. This presents an opportunity to integrate practical information from land users who daily interact with the invasive species thus defining priority areas for management intervention measures.

Numerous research (Geist *et al.*, 2006; Hernández *et al.*, 2016; Mertens & Lambin, 2000; Ramírez & Säumel, 2022; Zhou *et al.*, 2008; Zomlot *et al.*, 2017) have employed Land Use and Land Cover (LULC) trajectories to analyze spatiotemporal trends. Most of these studies emphasize the impacts of LULC trajectories on soil and water resources as well as their underlying drivers linked to biophysical features. However, Geist *et al.*, (2006) underscores the importance of understanding the rationale behind land users' management decisions. This understanding is crucial for interpreting the observed trajectories. This knowledge gap is essential for making context-specific decisions regarding appropriate management interventions that target the achievement of desired future trajectories in land management (Zhou *et al.*, 2008). Additionally, existing studies on land cover trajectories have not specifically addressed invasive species, making it challenging to generalize their findings to the management of *P. juliflora,* whose invasion process is intricate. Therefore, there is a need for analyzing *P. juliflora* trajectories and establishing connections with land management decisions.

2.7. Literature gaps filled by the study

Based on the highlighted body of knowledge, a disconnect exists between recognizing the importance of integrating *P. juliflora* management into sustainable land management (SLM) practices and effectively implementing such practices. The participatory process in selecting and implementing SLM practices is new in invasion management, yet its potential to enhance the chances of SLM adoption and implementation remains clear. Moreover, the perceived effectiveness of SLM practices is contingent on a specific context, which is crucial in determining whether these practices will be implemented consistently. However, there exist striking knowledge gaps on the relation between land users' perceived effectiveness of SLM practices and their preference to use them in managing invasion continually. The implications of a participatory process on land users' perceptions regarding SLM effectiveness and their considerations in selecting an SLM to implement needs to be examined.

The choices made by land users regarding the adoption and long-term utilization of SLM practices are vital in mitigating the impacts of land degradation. However, such decisions are shaped by systemic drivers that are context-specific but interconnected. Considering the complexities in invasion processes, addressing drivers that hinder effective invasion management demands a robust linkage between invasion patterns and associated drivers to land management decisions. Unfortunately, existing studies exploring such relationships concerning SLM implementation rarely focus on biological invasions. Their findings may, therefore, not be replicable to invasive species management. Integrating spatio-temporal satellite imagery made it possible to identify relevant invasion trajectories and link them to their associated management drivers. Likewise, this approach helped identify and match priority areas with appropriate management practices.

Finally, access to tenure rights, which is helpful in ensuring the implementation of SLM practices, should be addressed. Many studies have addressed barriers to access to tenure rights. These often focus on challenges in enforcing tenure rights. However, they fail to acknowledge that the nature of prevailing tenure systems may present themselves as barriers to accessing tenure rights. It is, therefore, essential to identify and understand the implication of tenure right barriers to SLM implementation. This will guide decision-makers on relevant measures to be taken to ensure access to tenure rights that are useful in implementing SLM practices.

2.8. Theoretical framework

The theoretical framework for this study is adapted from the human actor model of Wiesmann *et al.* (2011) , which presents actors as agents of change to sustainable development. It explains that local actors' actions in bringing change are an interplay of their activities, available means to implement the activities, and the meanings they attach to those activities. These actors' strategy of action is dynamic and multidirectional. For instance, the discrepancies between the outcomes of actors' activities and their perceived meanings or interpretations will likely trigger activity changes. This may be in the form of reallocating means and assigning them to alternative activities associated with more desirable outcomes as perceived by actors. Such discrepancies may also lead to adjustments in the meanings attached to certain activities, creating new rationales for actions.

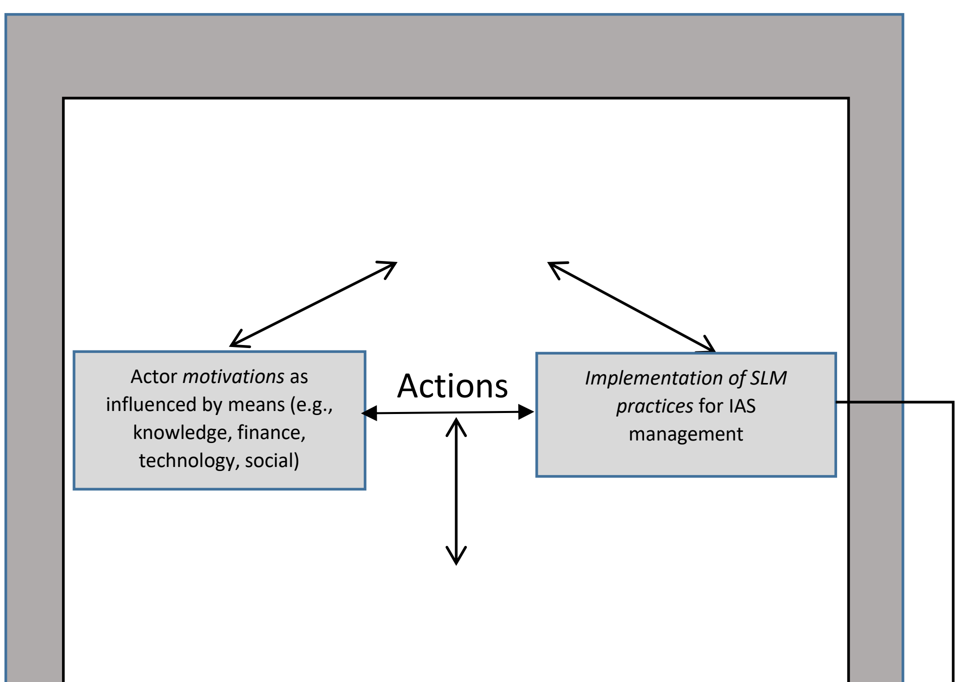
The actors' strategy of actions is shaped by dynamic drivers (social, economic, political, and environmental) which set the conditions for actions. This is because actors have a significant impact on the outcomes of activities and play a crucial role in determining the available resources that can be allocated to implement their respective actions. However, the primary rationale for action is determined by actors' perceptions, valuations, and interpretation of the outcomes of such conditions on their actions. Depending on the perceived conditions for action, actors are likely to adapt their activities to the dynamic conditions to minimize the chances of uncertainties, or they may modify the activities to improve the dynamic conditions of actions.

While the meaning of actions significantly defines the actors' rationale, it is contextualized in the societal social structures such as legislations, regulations, norms, beliefs, and institutions which predispose actors to believe, perceive, think, and act in specific ways. Bassett, (2007) confirms that societal institutions shape the meanings and actions of human beings by virtue of their social belonging. However, this is never a straightforward process because the community is a heterogeneous entity characterized by political and socio-economic inequalities and varying power relations among members and institutions. The model has widely been used in contextualizing actor agencies and rationales for their actions. This is depicted by previous studies (Biketti *et al.*, n.d.; Chinwe *et al.*, 2014) in which the framework was applied to evaluate farmers' reasoning and drivers influencing their adoption of soil and water conservation measures, ultimately impacting their livelihood resilience.

2.9. Conceptual framework.

The conceptual framework (Figure 2.1) is adapted from the human actor model. It presents the community as agents of change in adopting and implementing SLM practices aimed at controlling *P. juliflora* invasion. Successful implementation of effective SLM practices affects *P. juliflora* management by ensuring that land is actively used to reduce re-invasion. This has been considered to improve human livelihoods by restoring ecosystem services upon which they depend and enhancing their social and economic well-being. However, community members have varying perceptions of SLM practices, shaping their understanding of the implications of adopting different practices on their overall well-being.

Local actors' actions and effects on invasive species management are an interplay of their activities (decisions to implement SLM practices), means at their disposal to carry out the activities, and the meanings of such activities based on actors' interpretation. The means consist of material and non-material assets and resources: finances, technology, knowledge, and skills on how to implement SLM practices as well as land users' social capital depicting their social networks and relationships. In this study, the participatory process of engaging local actors through a systematic process of selecting SLM practices translates to knowledge as a means in the actor model. This is because participants will gain knowledge on what constitutes an effective selection of SLM practices. Access to relevant forms of means and the understanding of the outcome of their decisions determine local actors' actions concerning the implementation of SLM practices. This is a continuous process of mutual adaptation rather than unidirectional relation and depends on differences in land users' expected outcomes and actions (Wiesmann *et al.*, 2011).



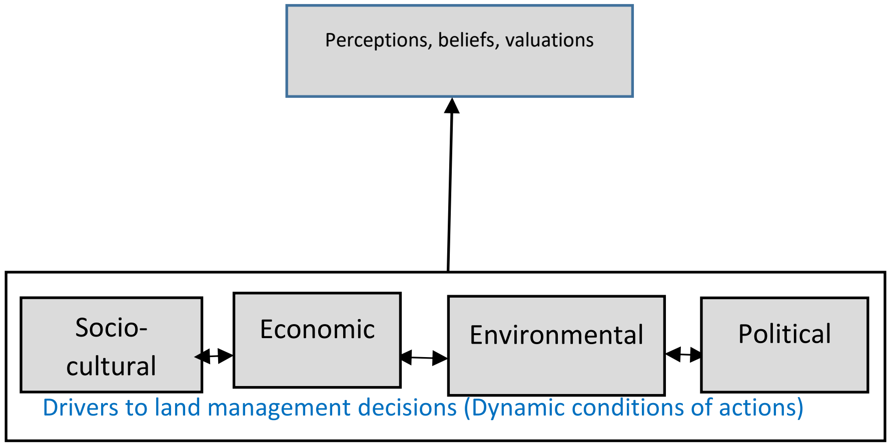


Figure 2. 1: Conceptual Framework inspired by the actors' model was utilized (Adapted from Wiesmann et al., 2011).

Despite many considerations shaping land users' decisions on SLM selection and implementation, their actions are embedded in culturally defined institutions, which shape land users' decisions on resource utilization and management. Land tenure has been widely considered a vital institutional aspect of SLM implementation. However, land tenure rights need to be enforced through functional institutions to be effective. In this respect, the existence and effectiveness of these institutions depend on the influence of their power relations on the perceptions, beliefs, decisions, and actions of society (Schwilch *et al.,* 2012). Additionally, external drivers influence the community's perceptions, valuations, and decisions in adopting and implementing SLM practices. This is because actors may not have control over some of the drivers, forcing them to adapt the SLM practices to the dynamic conditions of the external drivers (Wiesmann, *et al.,* 2011).

Therefore, their decisions in response to these drivers are reflected in the patterns of *P. juliflora* cover. The drivers are diverse but interrelated, ranging from social, economic, political, and economic drivers. (Jessop, 2014) illustrates that while political dominance indirectly influences who possess economic power to take the desired action, community members need to maintain their social relations by selecting politicians to make this a reality. This implies that institutional arrangements with strong social relations with their subjects who have access to economic power may be considered the most powerful in influencing land users' decisions on aspects of environmental restoration.

CHAPTER THREE: RESEARCH METHODOLOGY

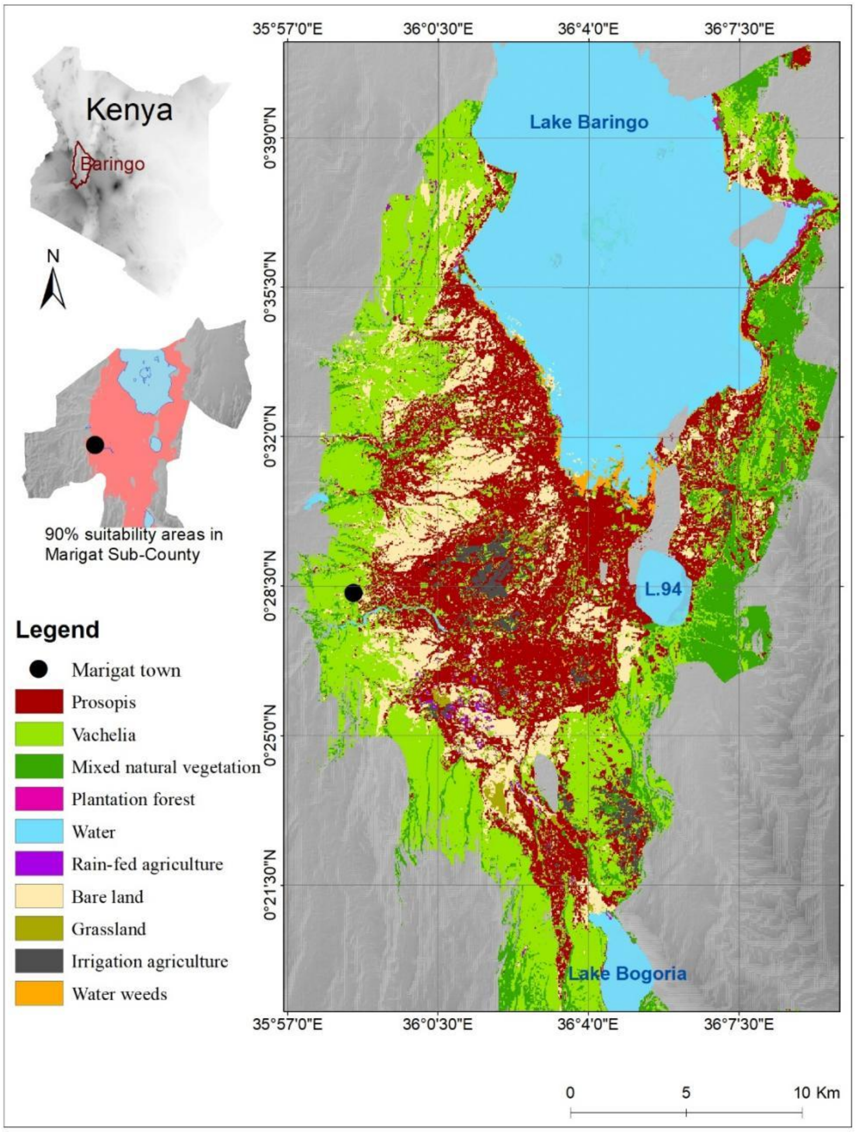
This chapter provides a comprehensive overview of the research methodology, including details about the study area, study design, sampling methods, sample size, data sources, data collection, and analysis methods.

3.1. Study area

The study area is Marigat Sub-County in Baringo County, which is located within longitudes 35°36'0" and 36°30'0" and latitudes 0°12'0" and 1°36'0" N. It covers an area of 11,075.3 km^2, with approximately 165 km^2 occupied by surface water. Marigat Sub-County is located in the eastern lowland areas of Baringo County, approximately 20 kilometers from either Lake Baringo and Bogoria (Map 3.1). It is known for its significant presence of *P. juliflora*, which is primarily concentrated in this sub-county. This area serves as a representative sample of the Arid and Semi-arid Areas (ASALs), which are heavily invaded by *P. juliflora* (Baringo County Annual Development Plan, 2016).

3.1.1. Climate

Baringo County, categorized as an Arid and Semi-Arid Land (ASAL) area, encounters a mean annual temperature of 24.6°C and receives an average annual rainfall of 635 mm. The rainfall in the region is characterized by two distinct rainy seasons. The short rainy season typically spans from October to November, while the long rainy season occurs between April and August (Kassilly, 2002a) . However, climate change is causing shifts in traditional weather patterns, leading to an increase in the occurrence of extreme weather events (MoALF, 2017) . Just like frequent flooding in Marigat, the Sub-County experiences severe drought seasons with the longest lasting for a period of 5 years between 200 and 2004, followed by another 2-years of severe drought between 2008-2009 ((Kosonei, *et al.*, 2017)



Map 3. 1: A visual depiction of the study area showcasing the study area's land covers and land uses in 2016, sourced and adapted from (Mbaabu *et al.*, 2019) and World Research Institute open data.

3.1.2. Vegetation

In the past, Baringo was primarily characterized by grasslands. Nevertheless, as a consequence of extensive human activities over a considerable period, the area has experienced substantial disruptions, leading to sparse vegetation predominantly composed of small trees and shrubs. According to Andersson (2005), the native vegetation in Marigat consists mainly of *Acacia* trees, particularly *A. tortillis* (Forssk), along with *Boscia spp, Balanites aegyptiae,* and *bushes* of *Salvadora persica*. However, over the years, vegetation degradation has been experienced in the area. Significant changes in vegetation cover were reported in early 2000 following an increase in drought intensity and duration.

The severe drought led to the degradation of native grasses that the pastoral communities depended on for fodder. Consequently, community members resorted to charcoal burning using the scarce native tree species as an alternative source of livelihood. This transformation of livelihood systems significantly declined the *Acacia* tree cover, especially in the lowlands of Marigat Sub-County consisting of the Ngambo, Logumgum, and Marigat areas. The intensive use and depletion of *Acacia* contributed to the government imposing a ban on the use of any native tree species for charcoal production. The native species have been encroached by *P. juliflora* (Mwangi & Swallow, 2008) which is progressively increasing its density and cover (Mbaabu, Ng, Schaffner, & Gichaba, 2019).

3.1.3. Demographics

The population of Marigat Sub-County is 109,760 people, 91% of whom are rural dwellers. Of this population, 50.2% are male, while female constitutes

49.8%. Baringo County's average household size of 5.02 and population density of 282 are higher than the national averages by 14% and 30%, respectively (KNBS, 2019) . Marigat Sub-County is home to various communities, including the Tugen (Samor) residing in the southeast, south, and southwest regions. The Njemps (Ilchamus) predominantly inhabit the low regions to the north, while the Pokot communities, who are primarily pastoralists, are found in the western part of the Sub-County. However, the urban areas within the county are cosmopolitan, hosting other ethnic groups with diversified cultures, practices, and lifestyles. The Pokots are primarily pastoralists who keep livestock and, in particular, goats. They rely on their livestock for sources of meat, milk, blood, and socio-cultural values. On the other hand, the Ilchamus and the Tugens are agro-pastoralists who keep livestock alongside practicing irrigation cultivation (County Government of Baringo, 2018; Dialogue & Land, 2016; GoK, 2014; Kassilly, 2002b).

3.1.4. Livelihood Sources

Community members in Marigat Sub-County are majorly pastoralists keeping goats and cattle as livestock and beekeeping as the main economic activities. However, small-scale farming for subsistence in the Perkerra irrigation scheme are also practiced in Kollowa, Marigat , and Barwessa (GoK, 2020).

By the 1980s, pastoralism predominated the study area, accounting for 98% of all livelihood sources. By 2016, these statistics had significantly changed, with 73 % of Marigat residents practicing agro-pastoralism, followed by charcoal production, which was the second source of income, as depicted by a weekly output of 750 bags of charcoal produced by residents of Marigat Sub-County (O. B. Adoyo &

Choge, 2018) . With the current ban on charcoal production in the area and the encroachment of most pasturelands by *P. juliflora* in Marigat, residents are likely to focus on cultivation to sustain their livelihoods. According to Mbaabu, *et al.* (2019), the contractual agreement between land users and the national irrigation board assures farmers of financial and technical suppo and a ready market for their produce. This has motivated land users to engage in irrigation farming, with maize seeds being the main cash crop in the area. The increasing demand for farmlands has resulted in the extension of irrigated lands.

3.1.5. Land ownership and land use

Most of the land in Marigat is under a communal tenure regime, accessed mainly through household heads (GoK, 2014) . However, while the land is strictly communal by de jure terms, a considerable percentage (15%) is privately claimed as a de facto agreement (Greiner, 2017). A few households have thus claimed interest in their private rights to land and formalized their ownership through title deeds. Approximately 30 % of the land in the study area is grazing, while the rest is distributed to farmlands, homesteads, and public places such as markets and public institutions (GoK, 2020).

3.2. Justification of the study area

Marigat Sub-County is the most invaded Sub-County representing heavily invaded areas in Baringo Country. Further, data on the fractional cover of *P. juliflora* in Marigat was useful in evaluating the trajectories of *P. juliflora* cover. Adapting the data for our analysis reduced duplication of work and minimized costs within our constrained budget. The observed fast and widespread invasion of *P. juliflora* in the area has adversely impacted the ecosystems and livelihoods of pastoral communities in Marigat. Marigat is dominated by a community tenure system characterized by patriarchal systems, ineffective tenure rights enforcement, and land governance structures. Therefore, it represented an opportunity to gather relevant information on challenges to collective SLM implementation, which is key to sustainable invasion management.

3.3. Study design

The research design utilized in the study was a quasi-experimental approach which was adopted to evaluate the role of a participatory selection of SLM practices (independent variable) on the chances of their continued use (dependent variable). A quasi-experiment design is applied in social sciences to compare the outcome of a psychosocial program or intervention between two distinct groups: one group subjected to the treatment under evaluation and the other control group subjected to no treatment at all or a placebo-type treatment (Thyer, 2013) . This research design consists of 3 components;1) selecting the unit of analysis, 2) determining the outcome or intervention to be evaluated, 3) Designing a credible methodology for administering the intervention, and 4) developing means of assessing the outcome of the administered intervention to the treatment and control groups (Rogers & Andrea, 2019; Thyer, 2013).

This study manipulated the independent variable by taking a group of randomly selected participants through a deliberative multi-criteria evaluation (DMCE) process. DMCE offers structured decision-making support by promoting structured deliberations and knowledge sharing among multi-stakeholders to reach a consensus. A detailed explanation of the participatory process is given in section 3.2.3. The assignment of respondents to this treatment (DMCE process) was purposive rather than through a random sampling. According to Pce *et al.* (2015), advocates for the use of a quasi-experiment instead of a correlation study design to enhance internal validity. This is because in a quasi-experiment, the researcher manipulates the independent variable before measuring the dependent variable, which reduces the issue of the directionality problem. The directionality problem refers to the possibility of the dependent variable affecting the independent variable, and by minimizing this problem, the study's internal validity is improved. Drivers to different *P. juliflora* cover trajectories as well as barriers to tenure rights enforcement were evaluated through qualitative research methods. This is because the information obtained from respondents was qualitative.

3.3.1. Sampling design and sample size

The study adopted a multistage sampling design incorporating purposive, cluster, stratified, and non-probabilistic convenience sampling. The methods allow successive selection of geographic locations and subjects from which to administer interviews and collect relevant information for the study (Turner, 2003) . While purposive sampling enhances the inclusion of the target subject matter, in this case, areas invaded by *P. juliflora,* cluster sampling made the study time and cost-effective (Memon *et al.*, 2020; Sedgwick, 2014; Taherdoost, 2018) by limiting the study area to a manageable extent. The following sections detail the sampling methods and their application in selecting subjects to be included in the study.

3.3.1.1. Purposive Sampling

Purposive sampling was used in selecting the study area. Marigat sub-county was purposively selected for this study since it is the most heavily invaded (63%) sub-county within Baringo County, where *P. juliflora* is a crucial driver to land use changes accounting for 86% loss in grasslands, 57% loss of irrigated cropland and a 37% loss of rainfed cropland between 1988 to 2016 (Mbaabu *et al.,* 2019). It is, therefore, a good representation of areas that *P. juliflora* heavily invades in the country. Rangelands and their associated resources are sensitive to invasion, and the impacts of *P. juliflora* have significant impacts on them. Therefore, Marigat Sub-County, a rangeland, was a suitable area to study the implications of *P. juliflora* invasion and its management on the pastoral communities and their livelihoods. The fact that the customary tenure system is the most prominent in the area makes it suitable for assessing tenure rights barriers, which are more pronounced in customary tenure systems. Purposive sampling also confined the study to a manageable extent, thus limiting the budgetary constraints of the study.

3.3.1.2. Cluster sampling

Cluster sampling involves defining homogeneous clusters based on geographical boundaries, followed by a sub-sampling process based on researchers' preferred choice, where subjects for the study are selected from each cluster (Kettenring, 2006; Kumar, 2014) . Cluster sampling is often used by research to minimize resource use where subjects to be studied are distributed over a large geographical area, thereby becoming costly and time-consuming considering the entire population in the study (Kettenring, 2006; Kumar, 2014; Taherdoost, 2018). A cluster consists of a population's natural distribution determined by geographical/ administrative boundaries or general practices. Cluster sampling assigns each cluster an equal probability to be selected for inclusion in a study independent of all the other clusters. However, a random selection may at times be time-consuming, expensive, and impractical leading to the commonly adopted practice of selecting clusters from conveniently defined geographical boundaries (Sedgwick, 2014).

In this study, cluster sampling was based on administrative boundaries whereby sub-location in the Marigat sub-county were clustered into heavily invaded and sparsely invaded sub-locations depending on the level of *P. juliflora* cover. Allocation of sub-locations into heavily or sparsely invaded areas was based on recently collected *P. juliflora* cover data from the Baringo woody weeds project (Mbaabu *et al.,* 2019). Cluster sampling helps in saving time and resources when the target population is distributed over a wide geographical area (Davis, 2005). A non-probabilistic convenience sampling was then used to select the households from the sub-locations. The questionnaires were administered to the household head or any senior member. Details of the non-probabilistic convenience sampling method are described in chapter 3.2.1.4 below.

3.3.1.3. Stratified random sampling.

Stratified sampling involves the division of the study population into sub-groups (also known as strata) that share the same characteristics (Taherdoost, 2018). It is used when the study expects variations between or among the groups. Stratified sampling was used to select respondents for the first objective of this study. Respondents who had undergone the participatory process formed one stratum, while those who did not undergo the participatory process formed the second stratum. Since few (30) respondents in the first strata underwent the participatory process of SLM selection, they were all included as sampling units. However, for the second strata that acted as a control group, an equal number of 30 respondents were further selected from the pre-selected sub-locations through non-probabilistic convenience sampling.

3.3.1.4. Non-probabilistic convenience sampling method.

The sampling units for the study were household heads. This is because they were considered to have stayed in the study area the longest and thereby had adequate information on the subject matter within their respective Sub-locations. The selection of households and inclusion of household heads in the study was conducted using a non-probabilistic convenience sampling method. This method involves selecting study subjects based on their willingness and availability to participate in the study. Unlike simple random sampling, which is impartial by offering each individual in a population an equal opportunity to be included in the study (Noor & Breth, 1996), the non-probabilistic convenience sampling method is limited by possibilities of biases (Kumar, 2014). However, its selection was informed by several limitations in using other more unbiased methods, such as simple random sampling. These drawbacks included 1) The unavailability of a sample frame and list of individual households in the study population, which is a mandatory condition for using the random sampling method; 2) The high chances of missing respondents from pre-selected households, which nullifies the credibility of the random selection process; 3) being a pastoral and rural community, the households are widely dispersed making the use of simple random sampling difficult, time-consuming, costly, and cumbersome.

Based on the above-anticipated challenges, non-probabilistic convenience sampling presented the most effective method of selecting households for the study. This method obtains a high response rate and reduces the cost and time of subject selection and data collection (Kumar, 2014). To minimize its potential biasness, it was combined with cluster and stratified sampling as described in preceding chapters. This ensured a wide range of locations were targeted to diversify responses and minimize the risk of over representing a particular response group or category.

3.3.1.5. Sampling size determination and distribution per objective.

The sample size refers to the total number of subjects required in a study to sufficiently test a hypothesis (Kaur, 2017). It is crucial to determine an appropriate sample size to ensure that research findings can lead to reasonable conclusions and allow for the generalization of results to the broader population of interest (Memon *et al.*, 2020). The sample size was derived based on the probability proportionate to population size (PPS) formula in Bellera *et al.,* (2012) as below:

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

n is the number of households to be selected.

p represents the proportion of the total population that is attributed to the specific target population. In cases where p is not known, it is conventionally assumed to be p = 0.5.

z is the z- statistic defining the level of confidence desired. A conventionally recommended confidence level (95%) has a z-statistic of 1.96.

ME is the margin of error assumed to be 0.08.

The equation is thus substituted as follows: $n = \frac{0.5(1-0.5)1.96^2}{0.08^2}$

$$\text{Sample size (n)} = 150 \text{ respondents}$$

The sample size was distributed proportionately to the number of households per sub-location (Table 3.1).

Table 3. 1: Proportionate distribution of sample size per sub-location

Sub-Location	No. of households	Sample size
Loiminang	410	11
Mukutani	255	7
Endao	173	5
Salabani	1008	26
Ngambo	655	17
Perkera	1423	36
Koriema	448	12
Eldume	361	10
Sabor	374	10
Sandai	256	7
Maji Ndege	324	9
Total	5687	150

Owing to the distinct nature of our objectives, the study did not use 150 questionnaires for each of the study objectives. First, 60 questionnaires were assigned for objective 1, which focused on the role of the participatory process on the chances of SLM implementation. Of the 60 respondents, 30 underwent the participatory process (deliberative multi-criteria evaluation) described in Chapter 3.3.2.1; hence they were involved in defining the objectives and strategies for managing invasion. They were also taught the impacts of invasion and the benefits of management. Because they represented a group that could implement or apply their knowledge of invasion management to the local community, we used the term "Local Implementation Group (LIGs)" to refer to them. However, the remaining 30 were randomly selected from the population and acted as a control group. In this study hereafter, they are referred to as the non-LIGs (Figure 3.1). In total, 60 respondents were assigned to objective one since it involved a comprehensive and costly process that could cater to a limited number of individuals. In addition, studies based on quasi-experiments have been confirmed to adopt smaller sample sizes compared to co-relational and descriptive studies (Kaur, 2017) . To balance the 30 participants whose training expenses were catered for, a similar number of respondents was assigned to the non-LIGs. Likewise, objective 1 had a comprehensive questionnaire that needed much attention to administer; hence 60 participants were realistic enough to be able to gather sufficient and accurate information to answer our research questions for this objective.

The second step of assigning respondents was on objective three, which aimed at evaluating drivers to land users' decisions in implementing SLM practices aimed at managing invasion. This objective was demanding in terms of time and resources owing to the fact that responses were all qualitative, and their effective administration had to be aided by the use of maps and posters on potential practices. In addition to the 60 respondents who answered questions on objective 1, an additional 20 respondents, totaling 80 respondents, were included to respond to the second and third objectives. Since the researcher personally administered all the questionnaires, responses from the 80 respondents were considered sufficient as the information gathered had reached a saturation point leading to multiple and unnecessary repetitions. These objectives required respondents to be well-experienced and knowledgeable about the invasion process in the study area. Therefore, in cases where the randomly selected respondents seemed to be giving irrelevant responses or had inadequate knowledge of the subject as encountered in the field, their responses were excluded and replaced with additional respondents to bring the number back to 80. Thus, some of the 60 respondents who answered questions on objective one skipped questions on objective three and proceeded to questions on objective four. Noting that we had five hotspot areas representing a high concentration of *P. juliflora* trajectories under investigation, we assigned 80 respondents proportionate to the population size per hotspot area (Figure 3.1).

The analysis of objective four was neither based on hotspot areas that needed local experience to answer questions on the participatory process, whose respondents were limited due to budgetary constraints. Still, it focused on tenure right barriers, which is of interest to the entire study sample. Therefore, all respondents who answered questions on objectives 1 and 3 were asked to respond to questions on objective four. To bring the number of respondents to 150 as had been calculated, an additional ten respondents were added and distributed per sub-location, as indicated in Figure 3.1 below.

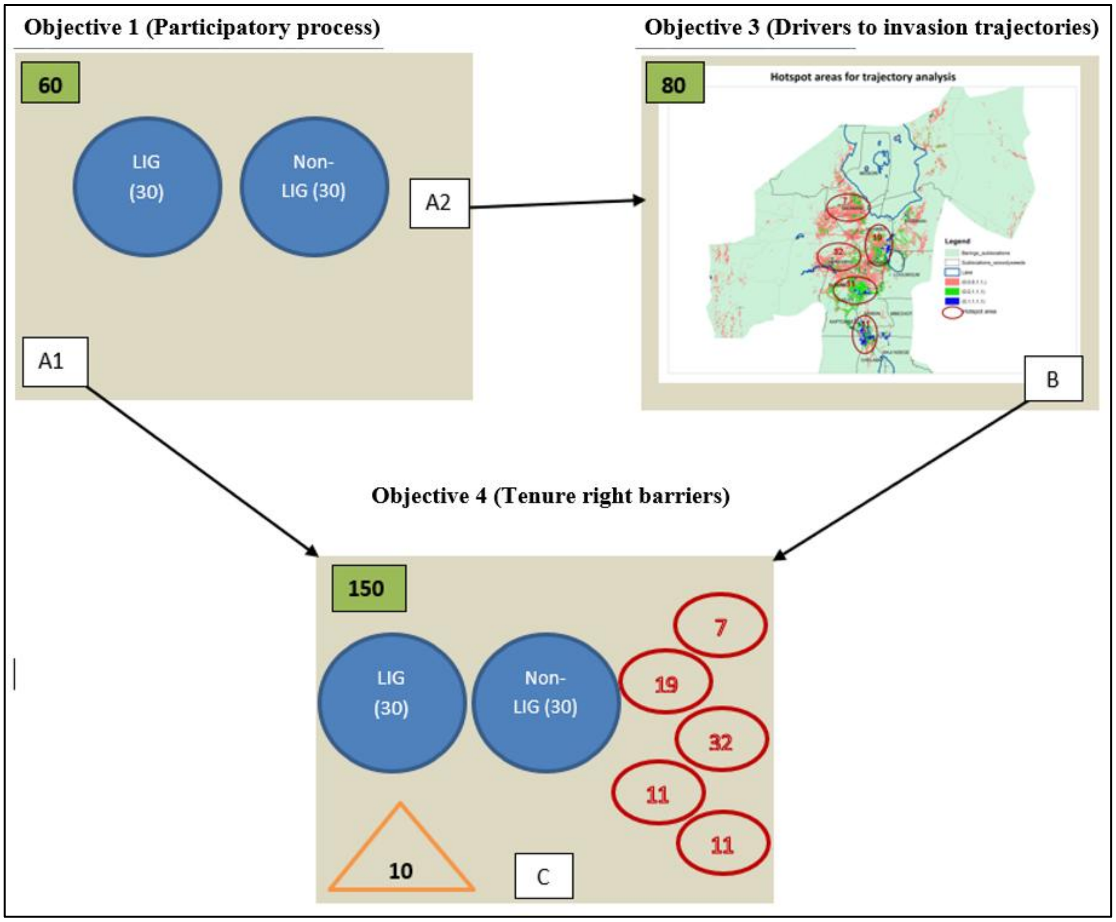


Figure 3. 1: Allocation of respondents to the 3 study objectives. A1: respondents who answered questions on objectives 1 and 4. A2: respondents who answered questions on objectives 1 and 3. B: 80 respondents who answered questions on objectives 3. C: 150 respondents.

3.4. Sources of data

3.4.1. Primary data source

Primary data from respondents were collected through key informants' interviews, household questionnaires, participant observation, focus group discussions, and deliberative multi-criteria evaluation (DMCE). They entail information on land users' perceptions of the effectiveness of SLM practices selected by the community versus those selected and implemented by scientists, drivers to trajectories of *P. juliflora* cover, existing land tenure systems and related tenure rights, as well as institutional roles and factors affecting enforcement of tenure rights needed for successful implementation of selected SLM practices. Drivers to different trajectories were categorized into four categories (table 3.2).

Table 3. 2: Drivers of trajectories for *P. juliflora* cover change.

Drivers	Examples
Social-cultural	Tenure systems, policies and regulations, community beliefs, demographic factors, inter-communal conflicts, livestock migration routes, community empowerment knowledge, and awareness creation.
Environmental	Climate variability, topography, natural disasters e.g., droughts and floods
Political	Political decisions on land utilization and management and their influence on policy formulations and development-related decision making
Economic	Subsidies, incentives, economic activities, and market creation

3.4.1.1. Deliberative Multi-Criteria Evaluation (DMCE)/ Participatory Process

DMCE is a structured decision-making process that combines the strengths of multi-criteria decision analysis with deliberations among citizens and scientists through knowledge sharing, negotiations, and consensus-building (Proctor & Drechsler, 2006) . The aspect of DMCE enhances transparency and ownership of decisions made by dispelling mistrust, a critical element in the implementation and scaling out of selected SLM strategies (Schwilch *et al.,* 2012 Proctor & Drechsler, 2006).

This approach was used to create awareness and enhance knowledge among the selected group, hereafter referred to as the local implementation group (LIG members), on the effective selection of SLM practices aimed at controlling *P. juliflora.* The LIG members entailed a multi-disciplinary team consisting of local land users, farmers, pastoralists, representatives of local, sub-county administration, public and private organizations, NGOs, and scientists who were tasked with demonstrating their experiences with the selection and implementation of SLM practices as well as advance their knowledge to inform effective selection.

Stakeholders were grouped into two groups based on whether they came from heavily or less invaded sub-locations. The level of invasion was derived from the results of the woody weeds project, which assessed the fractional cover of *P. juliflora* in Baringo (Rima *et al.,* 2019). Participants were taken through transect walks to identify the causes, impacts, and existing solutions to invasion to enable them to share knowledge and understand the implication and possible solutions to invasion. They deliberated and formulated their objectives for managing invasion under two management interventions depending on the level of invasion in their areas of origin. This was because management interventions were to be context-based and aimed at achieving a specific objective. Therefore, stakeholders from sparsely invaded areas formulated their objectives focusing on prevention and Early Detection and Rapid Response (EDRR) to *P. juliflora* spread in the less-invaded areas, while stakeholders from heavily invaded areas focused on EDRR and control of *P. juliflora* invasion.

With the assistance of scientists and relevant experts, stakeholders were taken through a world overview of conservation approaches and technologies (WOCAT) database to gain an understanding of SLM practices implemented elsewhere around the globe to manage invasion by *P. juliflora*. Information on the description, suitability, costs incurred, impacts, and cost-benefit analysis of each practice was discussed with the aid of posters.

Later, each group selected criteria upon which they evaluated the SLM practices. Relevant practices were selected and grouped into the three sustainability interventions (economic, socio-cultural, and environmental dimensions) and weighed against the selected criteria. The results were then aggregated to rank the alternative SLM practices for selection purposes based on the considered criteria.

This whole process entailed deliberations among stakeholders to reach a consensus on the best practices to implement to achieve their set objectives as well as meeting the three sustainability dimensions; economic viability, social acceptability, and environmental friendly. It was intended to equip the LIG members with knowledge on the effective selection of SLM practices, which would consequently inform their willingness to use the effectively selected SLM practices continuously.

A control group of respondents who had not participated in the DMCE process was randomly selected to assess the role of the participatory process in enhancing the better selection of SLM practices and their chances of land users' willingness to continuously use the SLM practices. The control group, hereafter referred to as the non-LIG members, was subjected to the same questions as the LIG members, and differences in their preferred practices for continuous use were analyzed. Differences in their perceptions of the need to manage invasion as well as their considerations in rating and selecting SLM practices, were also assessed.

3.4.1.2. Participatory mapping

Both stakeholder categories were also taken through a participatory mapping process of resources and assets within the Sub-County (Appendix 3.4). Small-scale base maps of the study area guided their visual interpretation of the location of significant resources and assets, which the invasion of *P. juliflora* could impact. A translucent tracing paper, upon which they traced features, was then overlayed and pinned on the base maps. The tracing paper was later on overlayed on a separate map of a similar scale but illustrated *P. juliflora* cover. This enabled them to identify hotspot areas where invasion level was likely to endanger existing resources and assets. The output was instrumental in informing their judgment on matching their selected management interventions to specific spatial contexts. Likewise, it acted as a resource base from which instrumental spatial datasets such as agricultural areas and grazing sites were digitized. The resultant functional units were later used to analyze drivers associated with the *P. juliflora* cover trajectories.

3.4.1.3. Semi-structured Questionnaires

Semi-structured questionnaires were administered to households to gather information on the implication of the participatory (DMCE) process on effective selection and the chances of continued use of selected SLM practices (Appendix 3.5). Respondents to these questions were the LIG members and an equivalent number of non-LIG members who acted as a control group, randomly selected from the study area. With three posters illustrating a set of SLM practices used in the participatory process, respondents ranked SLM practices based on which ones they would be most willing to implement continuously. They also gave reasons for their choices and rated their perceived effectiveness of the SLM practices.

The study compared land users perception on the effectiveness of SLM preferences and probed further questions in cases where there was a mismatch between experience and the presented output. For example, we sought explanations in cases where an SLM was least preferred and yet perceived to be very effective or vice versa. Respondents who wished to change their ranking at this point did so and gave reasons for the changes they made. We recorded the number of changes and the reason for each change made in the SLM ranking.

The questionnaires were also administered to land users to obtain information on tenure-right barriers hindering the successful implementation of SLM practices as well as on drivers to *P. juliflora* cover trends. Land users whose parcels of land were associated with striking *P. juliflora* cover trends in identified hotspot areas were interviewed on possible drivers to the trajectories.

Eighty land users were interviewed on this objective and were randomly selected from the hotspot areas. The distribution of respondents in each hotspot area was proportional to the population size of that area. To facilitate the interviews, three large-scale maps depicting distinct trajectories were prepared for each of the five hotspot areas. These maps were used as visual aids during the interviews. The respondents were asked open-ended questions regarding the factors influencing the trends in *P. juliflora* cover in their specific sub-locations, which corresponded to the hotspot areas. The main guiding questions for the interviews were as follows:

1. *Do you agree that the representation of P. juliflora cover trend in your sub-location is accurately depicted on the map?* This question aimed to verify the accuracy of the classification of trajectory types within the selected hotspot areas. Any contrasting opinions were duly noted, and further clarification was sought to obtain a more precise pattern.

2. *Please indicate the factors that you believe contributed to the occurrence of the respective pattern.* This was an open-ended question, and respondents exhausted all possible drivers they could think of. The words 'factors' and 'pattern' were used in the interviews instead of 'drivers' and 'trajectory' to clarify and minimize ambiguity.

3. *What is your most desired pattern of P. juliflora cover, and what factors limit the maintenance of your preferred P. juliflora pattern above?* This follow-up question was meant to verify previous responses regarding why the trajectory types were being observed in the hotspots. The questionnaires were also used to obtain information on the household characteristics of respondents.

3.2.3.4. Key informant interviews

Key informants consisting of the local authorities and county land officers were interviewed on the prevailing tenure regimes, existing tenure rights among different gender groups and their gender roles, as well as tenure right barriers limiting the implementation of SLM practices. A total of ten chiefs and one land registrar officer were interviewed (Appendix 3.6).

3.4.1.4. Semi-structured interviews

To triangulate responses obtained from the key informant interviews, 150 semi-structured questionnaires were employed as a means of gathering data from community members on tenure rights barriers inhibiting the implementation of SLM practices aimed at managing invasive species (distribution of the 150 questionnaires explained in figure 3.1). Respondents were asked about the nature of tenure rights within their community and the challenges such tenure systems pose to implementing SLM practices.

3.4.2. Secondary data sources

3.4.2.1. Spatial land use and land cover (LULC) datasets.

This study used pre-classified LULC data with a high classification accuracy of between 98.1% to 98.5%, adopted from Mbaabu *et al.* (2019). The LULC maps were derived from Landsat satellite imageries obtained from Landsat Surface Reflectance Climate Data Record. The selection of the dataset was based on the availability *P. juliflora* specific datasets for the designated timeframe and spatial extent. Likewise, the LULC maps were developed through a meticulous analysis process yielding high classification accuracies. The 30 m Landsat imagery that were atmospherically corrected were classified using a random Forest (RF) algorithm, as described by Mbaa-bu *et al.* (2019). To improve spectral differentiation of *P. juliflora*, which predominantly occurs at altitudes not exceeding 1500 m, both the wet and dry season datasets were employed, along with a digital elevation model from the Shuttle Radar Topography Mission (SRTM). This approach facilitated the identification of *P. juliflora*, known for its evergreen nature throughout the seasons. Training samples were collected to cross-validate the classification accuracy of the random forest model. The resulting land cover classification demonstrated accuracies of 98.5% and 98.1%, with corresponding kappa coefficients of 0.96% and 0.93s%, respectively (Mbaabu *et al.*, 2019). The land cover data for the study were provided at intervals of seven years, spanning from 1988 to 2016. This timeframe coincides with the introduction and subsequent visibility of *P. juliflora* on satellite imagery. Therefore, for the analysis conducted in this research, LULC maps for the years 1988, 1995, 2002, 2009, and 2016 were utilized and analyzed. The LULC datasets comprise 13 different land use/cover types, including the coverage of *P. juliflora*, which is the primary subject of investigation in this study.

Additionally, the study made use of thematic shapefiles from the World Resources Institute (WRI) and OpenStreetData websites to facilitate overlay analyses. These spatial shapefiles, freely available online, encompass information on road networks, rivers, and lakes. Moreover, we obtained a settlement layer with a resolution of 30 meters from the Connectivity Lab and Center for International Earth Science Information Network. This layer provides a highly detailed representation of settlement boundaries, making it a reliable indicator of inhabited regions. It is worth noting, however, that the data does not include information regarding population distribution on a per-building basis.

The settlement raster layer has values of 1, where the settlement or a building was detected in satellite imagery (CIESIN, 2016). The population data for the latest census distributed per polling station was obtained from the 2019 census data. Finally, land use activities such as cultivated and grazing lands were digitized and guided by a participatory mapping process with local stakeholders.

3.5. Data analysis

This section describes the methods used in analyzing data in the study. The land cover datasets in the study underwent analysis using spatial-temporal analysis techniques to examine the trends in *P. juliflora* cover. Additionally, thematic analysis was employed to investigate the factors influencing these trends. Furthermore, inferential statistics were utilized to draw meaningful conclusions from the primary information collected from respondents. The preceding sections describe each of these analysis methods.

3.5.1. Analysis of spatio-temporal invasion trajectories

Land cover maps were used to determine whether *P. juliflora* is present or absent in each pixel. These land cover maps were reclassified into binary maps. These binary maps only indicate the presence or absence of *P. juliflora* in each pixel. The used the 'combine' function in ArcMap 10.4 to assign new pixel values based on the unique combinations of input pixel values from the 5 input binary map layers for the 5 years. The outcome of this analysis is a layer that displays 32 spatio-temporal trajectories of *P. juliflora* coverage, illustrating the distinct patterns of presence and/or absence of *P. juliflora* between the years 1988 and 2016. For example, the sequence represented by 0 – 0 – 0 – 1 – 1 indicates (for the selected 30 x 30 meters raster cell) the absence of *P. juliflora* between the years 1988 to 2002 but the presence of *P. juliflora* in 2009 and 2016 (Table 3.3).

Table 3. 3: Selected striking types of trajectories

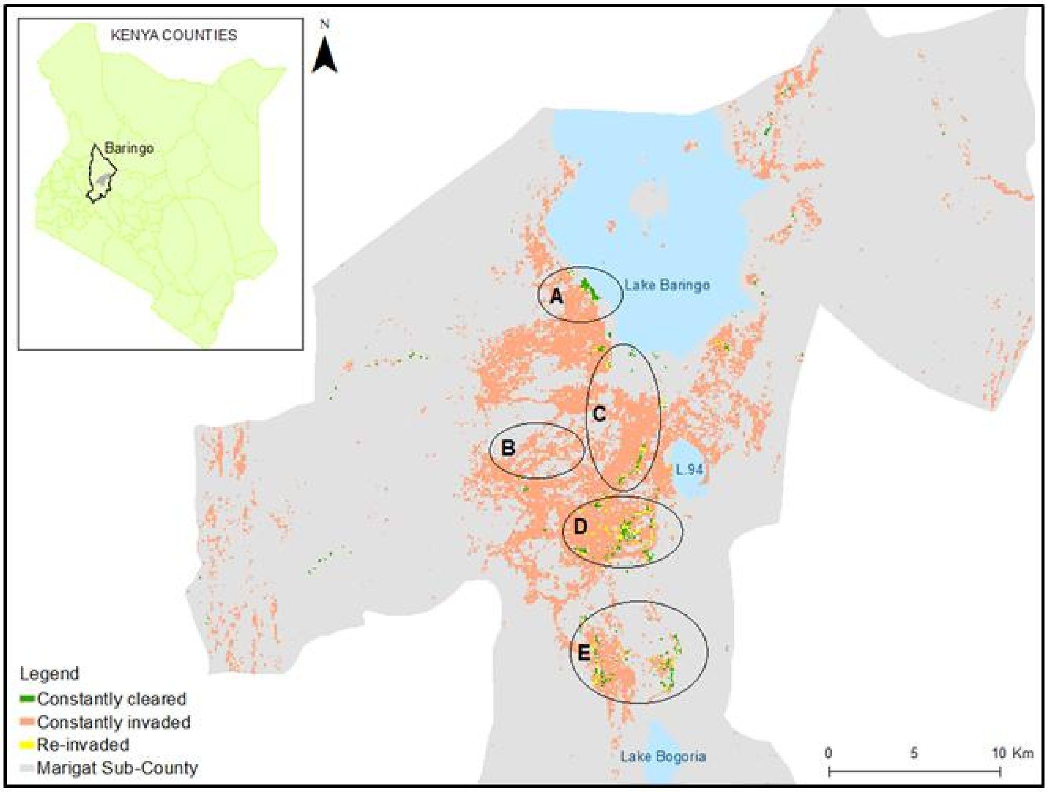
Value	Count	1988	1995	2002	2009	2016
1	10222861	0	0	0	0	0
2	727883	0	0	0	0	1
3	638958	0	0	0	1	0
4	295397	0	0	0	1	1
5	55819	0	0	1	1	0
6	52289	0	0	1	1	1
7	50319	0	0	1	0	0
8	20052	0	1	0	0	0
9	17761	0	0	1	0	1
10	9705	0	1	1	0	0
11	8448	1	0	0	0	0
12	6906	0	1	0	1	0
13	6165	0	1	1	1	1
14	4849	0	1	0	1	1
15	4778	0	1	1	1	0
16	3341	0	1	0	0	1
17	3231	1	0	0	1	0
18	3108	1	0	0	1	1
19	2584	0	1	1	0	1
20	2268	1	0	0	0	1
21	1428	1	0	1	1	1
22	1259	1	1	0	0	0
23	1120	1	1	1	0	0
24	743	1	0	1	0	0
25	721	1	1	1	1	1
26	713	1	0	1	1	0
27	546	1	1	0	1	0
28	522	1	1	0	1	1
29	350	1	0	1	0	1
30	277	1	1	1	1	0
31	237	1	1	1	0	1
32	197	1	1	0	0	1

Explanation of the table: The values 0 and 1 are used to indicate the absence and presence of *P. juliflora*, respectively. The "Count" refers to the number of pixels within Marigat Sub-County that correspond to each trajectory. Each pixel has a size of 30x30 meters (Source: Mbaabu *et al.,* 2019).

Some trajectories which only covered very small areas, or those that were inconclusive in terms of the invasion trend were excluded. The remaining 13 trajectories were clustered into three groups broadly reflecting three possible types of *P. juliflora* management decisions by land users: (1) systematic *P. juliflora* adoption and implementation of sustainable land management (SLM) practices to control invasion; (2) adoption but subsequent abandonment of SLM practices; (3) no attempt to adopt and implement SLM practices. In other words, the study assumed that areas, where *P. juliflora* has never been cleared since they were first invaded, represent a failure to adopt SLM practices while areas that remained *P. juliflora* -free since they were first cleared represent land users' decisions to adopt and continually implement SLM practices. Finally, re-invaded areas will most likely represent land users' decisions to abandon already adopted SLM practices.

The above-mentioned three striking categories of trajectories were selected based on their coverage, relevance to management options, and distribution pattern. This was conducted in three main stages; 1) Trajectories that did not belong to the three management options were excluded. The focus was on areas that were never cleared since their initial invasion, areas that remained cleared since their initial clearance, and the re-invaded areas. 2) the resultant trajectories were then filtered by selecting visually evident patterns based on the number of pixels they covered and were consistently occurring for a minimum of two consecutive timeframes. This ensured that trajectories that occurred either spontaneously or as a result of possible misclassification were excluded from further analyses. As an exception, the study included spontaneously occurring trajectories that were localized in a definite pattern as they indicated an association with a specific management strategy. Likewise, patterns that do not cover a large area but are clustered in precise locations were included in the selection as these patterns could potentially indicate distinct management strategies implemented within well-defined localities On the contrary, trajectories represented by a high number of pixels but scattered all over the sub-county without clear spatial patterns were excluded, as they did not allow for making meaningful interpretations of possible associated drivers 3) A particular trajectory of constantly cleared areas is linearly occurring along the lake shores. These trajectories were also excluded as they represent the natural choking of *P. juliflora* by the rising water levels. Thus, they may not represent active clearing based on land users' decisions, which is the basis for this study.

Block statistic was then applied to filter unnecessary noise and produce more distinct polygons with minimized pixel variations. Block statistics is a neighborhood operation in ArcGIS 10.4, which sub-divides pixels into non-overlapping blocks and assigns each pixel a value equal to the majority value within their corresponding block. Five hotspot areas were then selected for the study depending on the visual concentration of the three *P. juliflora* trajectories (Map 3.2). Thematic shapefiles of environmental and socio-economic factors were overlaid with the output and analyzed to identify their correlation with respective trajectories.



Map 3. 2: Hotspot areas (black circles with alphabetical letters -A to E) for the *P. juliflora* trajectories. The pink patches represent areas that have never been cleared since their initial invasion, green patches represent areas that have never been re-invaded

3.5.2. Classification accuracy assessment

To assess the accuracy of our classification approach, the study compared the re-classified datasets with pre-classified images that served as the ground truth data. The evaluation was conducted using a confusion matrix, which includes three types of accuracies and kappa coefficients. The kappa values measure the classification performance by comparing it to random assignment of values. These values reflect the degree of alignment (on a scale of 0 to 1), between the classified LULC classes and the reference classes used as ground truth data. A higher kappa value signifies a more accurate classification, with a value of 1 representing complete similarity between the classified and ground truth data. Our study achieved a total classification accuracy ranging from 98.96% to 99.14%, with kappa coefficients ranging from 0.67 to 0.84 (Table 3.4).

Table 3. 4: Confusion matrix

	Classified data	**Reference data**					
Year	Land cover Types	*Prosopis*	No *Prosopis*	Producer's Accuracy (%)	User`s Accuracy (%)	Overall Accuracy (%)	Kappa statistics
1988	*Prosopis*	101	22	81.45	82.1	99.5	0.8
	Not *Prosopis*	23	8321	99.74	99.7		
1995	*Prosopis*	135	35	88.82	79.4	99.4	0.8
	Not *Prosopis*	17	8866	99.61	99.8		
2002	*Prosopis*	70	30	64.81	70.0	99.2	0.7
	Not *Prosopis*	38	8523	99.65	99.6		
2009	*Prosopis*	179	50	81.36	78.2	99.0	0.8
	Not *Prosopis*	41	8487	99.41	99.5		
2016	*Prosopis*	170	52	85.43	76.6	99.1	0.8
	Not *Prosopis*	29	9190	99.44	99.7		

The confusion matrix provides an overview of the performance of the reclassification of land use/land cover (LULC) data from 1988 to 2016.

3.5.3. Analysis of spatial autocorrelation of trajectory categories.

utilized Moran's I autocorrelation to examine the spatial clustering of trajectory categories. Moran's Index is a widely used measure of global spatial autocorrelation that helps us understand the spatial distribution of a phenomenon and determine if there is significant aggregation in the observed spatial patterns (Wang *et al.*, 2019) . The coefficient of Moran's Index ranges between -1 and +1 and is standardized. Positive coefficients indicate positive spatial autocorrelation, indicating an aggregation or clustering of values for the phenomenon under investigation. Conversely, negative coefficients indicate negative spatial autocorrelation, suggesting dispersion or spatial heterogeneity. A coefficient of 0 signifies a random distribution of the phenomenon under investigation. In order to assess the strength and significance of spatial clustering, we analyzed the z-score and p-values values respectively (Ye *et al.*, 2020) . Thus, our hypotheses for Moran's I spatial autocorrelation is;

Ho: Values for the 3 trajectory categories are randomly dispersed.

HA: The spatial distribution of the trajectory categories is clustered as influenced by land users' management decisions.

Moran's I scatterplot consists of a graph with four quadrats that display the relationship between the standardized observed values (in the x-axis) and the lagged weighted variable of the observed values (in the y-axis). The term "lag" represents the average of neighboring values of a location. In this case, it is the average spatial weight of pixels within a neighborhood. The neighborhood includes pixels that border each trajectory pixel in such a way that the spatial weights are only assigned to pixels that neighbor the variable under observation. Points on the upper right and lower left quadrants indicate a positive spatial autocorrelation. This means there is a similarity in the values that neighbor the observed values, evidence of clustering. On the other hand, points on the upper left and lower right quadrants indicate a negative spatial autocorrelation, thus dispersion. The slope of the fitted line indicates Moran's I coefficient (Wang *et al.*, 2019).

3.5.4. Analysis of drivers of land users' management decisions.

The open-ended responses, along with the associated socio-demographic data, were recorded in Excel. To facilitate analysis, these inputs were merged into a single string ID and converted to a text format. The data was then exported to ATLAS.ti for further analysis (Figure 3.2).

Reasons_for_constant_invasion
ID_String

1. Communal land-no one is committed as there is fewer benefits derived
2. Inadequate funds to control Prosopis
3. Lack of timely knowledge on potential impacts

1-Ngambo-40-High-M-Married

1. Lack of knowledge on impacts
2. Inadequate funds for management

2-Salabani-37.3-Low-F-Married

3-Salabani-37.3-Low-F-Married

1. No man's land hence no one held responsible for managing them
2. Pasture land-Restricted to grazing and not cultivation yet people can only clear areas they to cultivate
3. Suitable soils-clay and sandy

4-Salabani-37.3-Low-M-Married

Figure 3. 2: The text format of the first five respondents' answers pertaining to the drivers of constant invasion is presented. The responses are shown in black font, while the characteristics of the respondents are highlighted in red font. Each respondent's information is separated from the next by spaces. For example, the first respondent is a married male from Ngambo, which has a high *P. juliflora* cover of 40%.

The responses were then coded and categorized into themes related to socio-cultural, environmental, economic, and political drivers (Table 3.5). This was to assist in ranking the drivers from the most to least prominent in explaining the occurrence of the three trajectory types.

Open and list coding was used to minimize the chances of assigning the wrong code to a quotation. Open coding entails highlighting a quotation and entering a new code to be assigned to it.

Table 3. 5: Thematic groups identified within the four-driver categories.

Social	**Environmental**	**Economic**	**Political**
Land user characteristics and experiences	Environmental and climatic conditions	Resources (Monetary)	The exploitation of land users by the government
Livelihood diversification	Nature of *P. juliflora*	Poor pricing of farm produce	Inadequate government support
Benefits derived from *P. juliflora*	Availability of water for irrigation	Market availability	Lack of prioritization of invasion management by the government
Conflicts /disputes			Government incentives
Cultural beliefs and practices			
Tenure system			
Resources (knowledge, skills)			
Land management practices			

On the other hand, list coding provides for the selection of existing code and assigns it to the highlighted quotation. In both cases, assigning a code to each quotation is exclusively decided upon by the researcher rather than the software. This process ensures that quotations are highlighted one by one, critically read, and assigned the most appropriate existing code (for list coding), or a new code is assigned in cases where a corresponding code is missing (for open coding). Nevertheless, it is crucial to recognize that coding has inherent limitations as it is dependent on the researcher's interpretation of the subject matter and the context in which each response was provided. To minimize the possibility of misinterpreting the responses and assigning incorrect codes, the researcher conducted all interviews personally, ensuring any unclear concepts were clarified. Subsequently, the data was organized into c-coefficient tables to analyze the connections between codes and code groups, facilitating a comprehensive examination of their associations. The c-coefficient table displays c-indices, which indicate the existence and strength of the association between selected codes or code groups. The coefficients range from 0, indicating no co-occurrence of codes, to 1, indicating that the codes are always assigned to the same quotation or response (Friese, 2019). The c-coefficient (c), also known as the c-index, is calculated below;

$$c = n12/(n1 + n2 - n12)$$

Whereby n1 and n2 are the occurrence frequency of two co-occurring codes, c1, and c2, while n12 is the co-occurrence frequency of two codes (Friese, 2019)

Two scenarios might distort results in ATLAS. ti. These are unequal frequencies between the codes being related and assigning two overlapping quotations to the same code. While the existence of co-occurring codes whose frequencies differ by more than the threshold of 5 indicates distortion by unequal frequencies, results with c-coefficients that are out of the allowable range (0 to 1) indicate distortion due to redundant coding (Friese, 2019) . Unequal frequencies distorted our results as the number of responses per respondent and question differed. This is because the questions were open-ended. Thus, the number of responses depended on one's knowledge and experience. The affected c-coefficients were normalized to rectify the distortion. The output was later presented in network views to give a visual impression of the relationship between and among the codes.

3.5.5. Inferential statistics.

The quantitative data from the research responses were analyzed through inferential statistics, which uses sample data to infer the general population. Inferential Statistics draws conclusions about a population based on the analysis or observation of a sample (Amin, 2019) . An independent samples t-test was used to measure the differences in the responses between the LIG and non-LIG members. T-test is a parametric test that determines the existence of a significant difference in the means of 2 groups. The independent samples t-test was selected for this analysis as the LIG and non-LIG members are separate heterogeneous and unrelated samples that assume a normal distribution. Descriptive statistics such as percentages, frequency counts, and means were used to analyze general characteristics and descriptions of respondents,

3.6. Ethical issues and how they were addressed.

The purpose of ethics in research is to ensure that participants are protected morally and ethically by ensuring that research activities do not adversely impact targeted respondents. This study observed the major issues of ethical concerns in research, among which are; informed consent, respect for confidentiality and privacy, as well as transparency concerning the purpose and scope of the study (Fouka & Mantzorou, 2012). Authors whose work or data were used in this study have been duly acknowledged, and consent was requested where necessary.

3.6.1. Right to privacy and informed consent

This right protects respondents by ensuring the information given to them is not shared without their consent (Burns & Grove, 2003). Therefore, the respondent must voluntarily and knowingly consent to participate in any research activity (Igfedha and Makau, 2016). Such deliberate participation ensures that respondents are protected from emotional and physical harm, thereby protecting their honesty (Igfedha and Makau, 2016). During this study, the researchers protected all the information given in confidentiality by respondents unless permitted by respective respondents. Likewise, the identity of respondents was made anonymous for participants who did not want their feedback to be directly associated with them.

3.6.2. Right to full disclosure

The right to full disclosure means that the researcher comprehensively explains the nature of the research, the role of the participant, the objective of the study, and the potential impacts of the study, as well as clarifying the right of the respondents to decline to participate in the research (Burns & Grove 2003). To comply with the right to full disclosure, the researcher explained the intent and effects of our research to the potential respondents and sought their consent to participate in the study, either through interviews or participation in the LIG process. Since the questionnaires were comprehensive and time-consuming, participants were also made aware of the approximate time they were likely to spend during their participation. Respondents were assured of non – prejudicial treatment of all respondents irrespective of their decision to participate in the study or withdraw.

CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter presents the results and discussions of the study, drawing upon findings from existing empirical studies. The organization of the chapter follows the four objectives of the study. Consequently, the results and discussions about the first objective are presented first, followed by subsequent objectives. Each chapter begins with presenting the findings in the first section and then proceeds to discuss these findings in light of previous studies in the last section.

4.1. Stakeholder-Led participatory processes and its contribution to the effective selection and chances of continued use of SLM practices

This first objective evaluated the effect of the participatory process, herein referred to as the Local Implementation Groups (LIG) process, in shaping participants' perceptions and decision-making on SLM implementation during the study period. The results compared responses between the LIG and non-LIG members (control group) based on their perceptions of the need to manage invasion, their most preferred SLM practices, as well as factors influencing their preferences and perceptions.

4.1.1. Perceptions of the need to implement SLM practices

The study's findings revealed a statistically significant difference ($p<0.05$) in perceptions between the LIG (Local Implementation Groups) and non-LIG members regarding the importance of managing invasion (refer to Figure 4.1 B). Using a Likert scale that spans from 1 for ‘strongly disagree’, to 5 for ‘strongly agree’, it was observed that 89% of LIG members agreed or strongly agreed with the necessity of managing the spread of invasive species, while only 11% disagreed. None of the LIG members was undecided, i.e., given a rating of 3 (neutral) on the Likert scale - as to whether there is a need to manage invasion. As for the non-LIG members, only 38% either agreed or strongly agreed that there is a need to manage invasion, while close to half of them (43%) disagreed on the need to manage invasion (Figure 4.1 A). It is also striking that a considerable number (19%) of the non-LIGs were undecided on whether the invasion by *P. juliflora* should be managed.

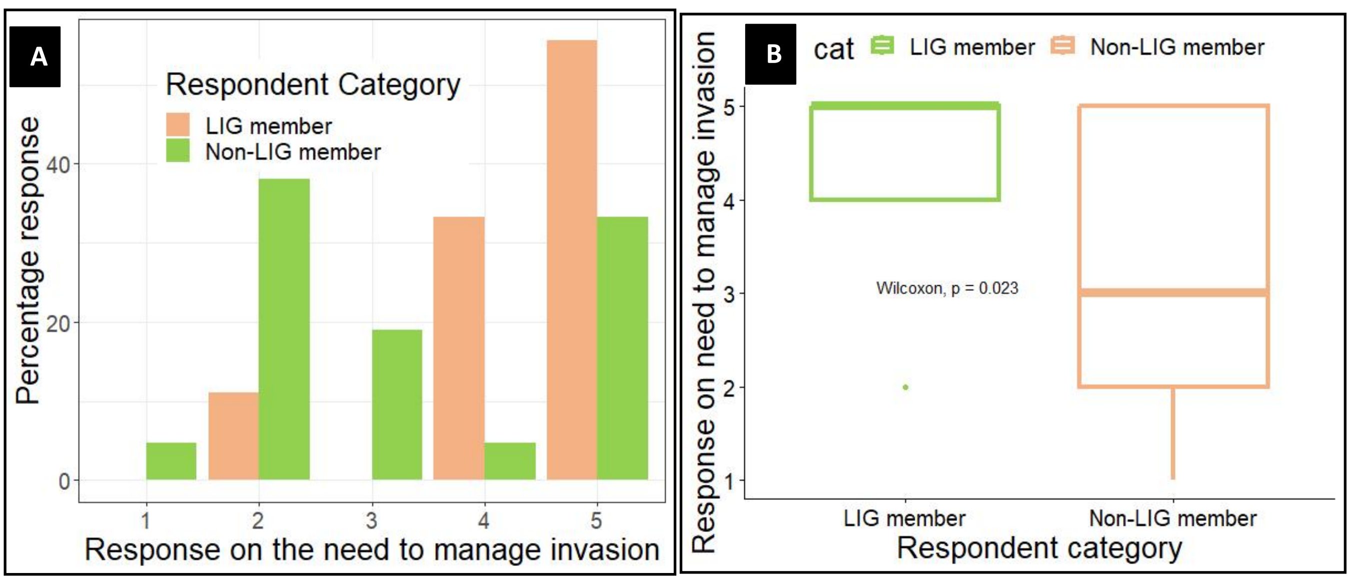


Figure 4. 1: Respondents' perception of the need to manage *P. juliflora* represented as a bar graph (A) and box plot(B). The box plot displays a p-value ($p<0.05$), which indicates a noteworthy statistical distinction in the perceptions of LIG and non-LIG members regarding the need to manage invasion. The respondents' opinions on the need for invasion management were captured using a Likert scale, ranging between 5 (Strongly agree) to 1 (Strongly disagree).

4.1.2. Considerations in selecting the most preferred SLM practices

The primary motivation to implement an SLM was grouped into three categories (environmental, economic, and socio-cultural). The economic dimension is the main driver motivating both the LIG (60%) and non-LIG (47%) members to implement SLM practices (Figure 4. 2). Whereas the need to conserve the environment motivated a third (33%) of the LIG members to implement SLM practices, only 19% of the non-LIG members were driven by the environmental dimensions to implement SLM practices. Similarly, the proportion of the non-LIG members motivated by socio-cultural factors to implement SLMs is five times that of the LIG members.

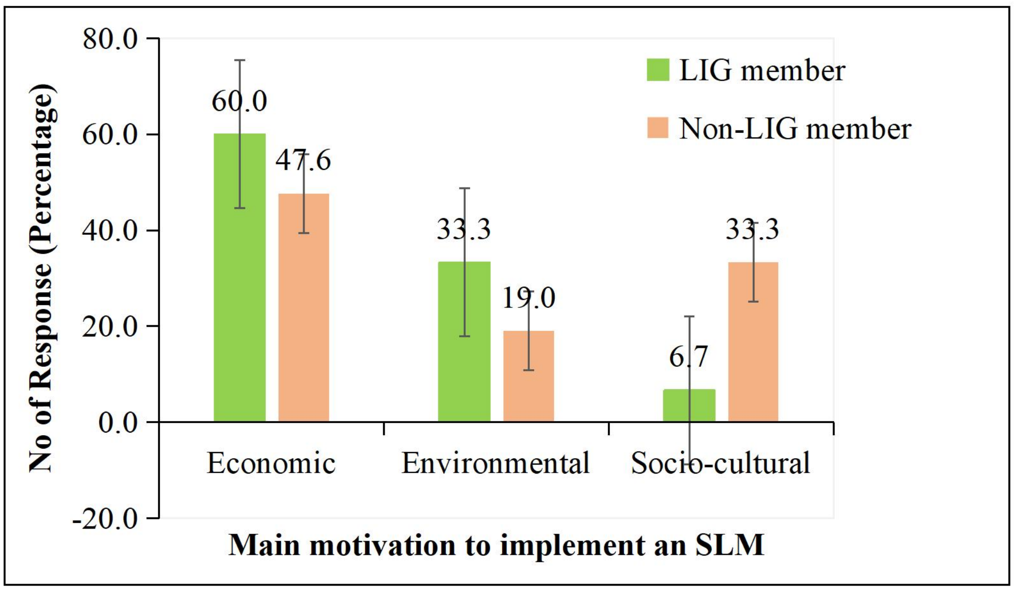


Figure 4. 2: Main motivation to implement an SLM. The vertical lines through the bar plots are error bars illustrating the data variability around the mean.

4.1.3. Selection of most preferred SLM practices by respondents

The study aimed at highlighting the contribution of the participatory process to respondents' preferences for specific practices. It, therefore, examined variations between the LIG and non-LIG members' preferences for SLM practices to be implemented. Findings gave insight into the role of a structured participatory process in shaping land users' selection preferences for SLM practices.

4.1.3.1. Most preferred prevention practices.

Both respondent categories (LIG-members and non-LIG members) preferred less prohibitive measures such as reseeding and surveillance of uninvaded areas (Figure 4.3) rather than fencing, prohibition of livestock in protected areas, and quarantine which include more constraints. Still, there were twice as many LIG members than non-LIG members who selected prohibitive measures.

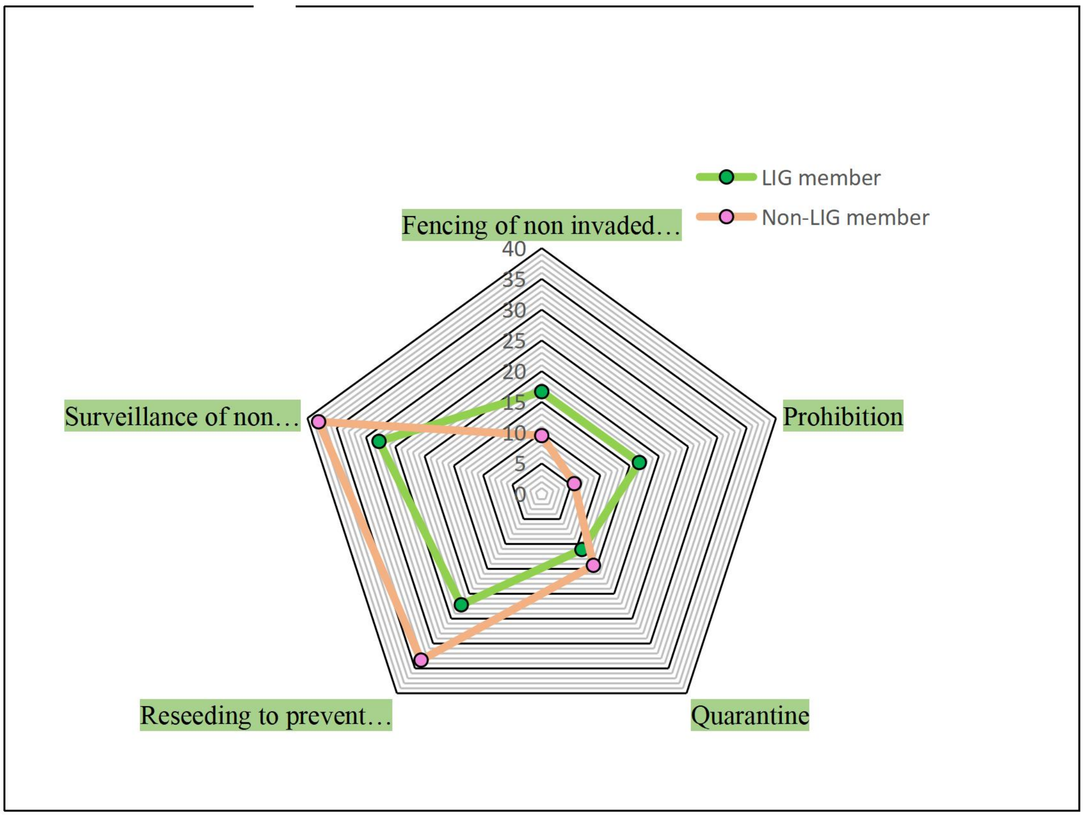


Figure 4. 3: Most preferred Prevention practices

Results in Figure 4.4 below show that the non-LIG members overestimated the effectiveness of their preferred prevention practices, i.e., fencing and prohibition, which were perceived by 100% of the non-LIGs to be very effective, thus assigned a rating of 5 (very effective) on a Likert scale. However, 33% of the non-LIG members who preferred quarantine perceived it not to be very effective since it may not be embraced by the community members owing to its incompatibility with their pastoralists' way of life. Likewise, concerns were raised about the possibility of effectively managing animal waste from quarantined livestock to prevent the dispersal of *P. juliflora* seeds to non-invaded areas.

Unlike the non-LIG members, 100% of the LIG members who selected quarantine as their preferred prevention practice perceived it to be very effective. This perception was based on the assumption that a quarantine process effectively destroys *P. juliflora* seeds from animal waste, thus preventing their dispersal to uninvaded areas. Despite acknowledging their limited effectiveness, 25% of the LIG members still preferred fencing and prohibiting access to uninvaded parcels (Figure 4.4).

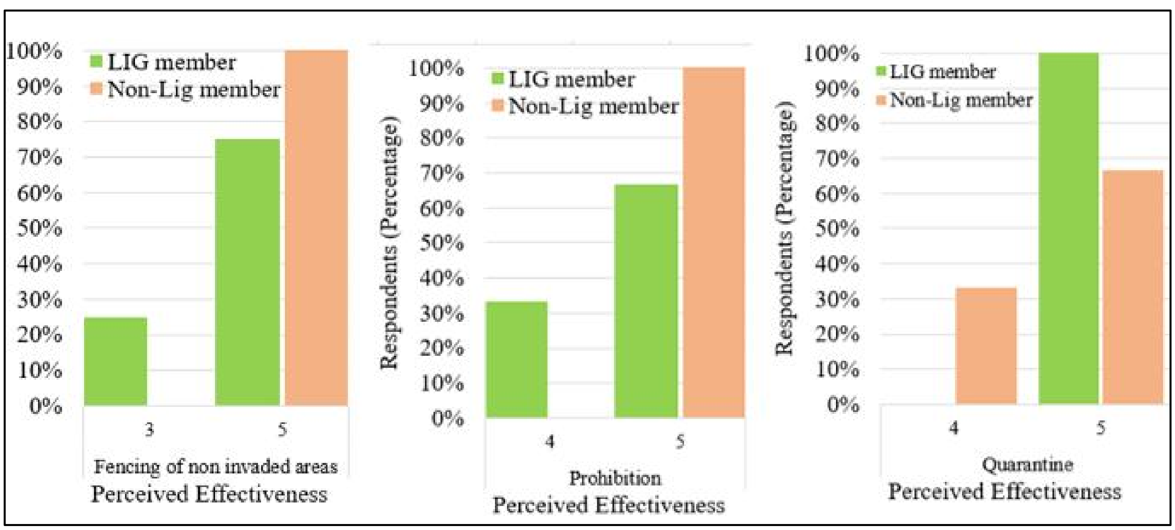


Figure 4. 4: Perceived effectiveness of prohibitive prevention SLM practices by respondents. Responses on the perceived SLM effectiveness are measured on a Likert scale ranging from 1(Strongly disagree) to 5(strongly agree).

4.1.3.2. Most preferred early detection and rapid response (EDRR) practices

The respondents' selection of EDRR practices indicates that both categories of respondents are less inclined to apply technology in managing invasion. Thus, surveillance using smartphones was the least preferred practice (Figure 4.5). While no clear distinction exists in EDRR practice preference between the two groups, the result shows that priority is given to practices that integrate surveillance with other active land management approaches, such as uprooting, cutting, and burning of the cut *P. juliflora* trees. The difference in the assessment could be attributed to the knowledge gained by LIG members about the benefits and limitations of each practice, thus making them acknowledge the strengths and weaknesses of the practices. For instance, according to LIG members, surveillance using smartphones and uprooting cannot effectively manage invasion unless integrated with active land-use practices such as reseeding or crop cultivation.

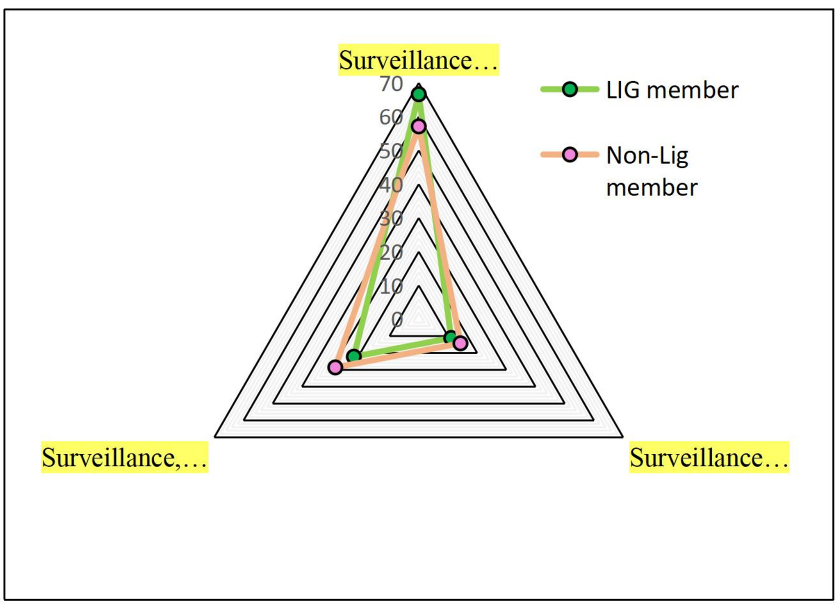


Figure 4. 5: Most preferred EDRR SLM practices

4.1.3.3. Most Preferred Control Practices

The most preferred control practices are integrating control and restoration practices, i.e., uproot and cultivate, enclosure and reseeding, and cutting below ground with reseeding (Figure 4.6). However, the non-LIG members were the only ones who preferred control by utilization through charcoal production- one of the primary income sources derived from *P. juliflora* (figure 4.6).

Unlike the non-LIG members, the LIG members seem to acknowledge the limitations of the practices on effective management of the environment. None of them preferred control through utilization nor control by cut-stump treatment (Figure 4.6).

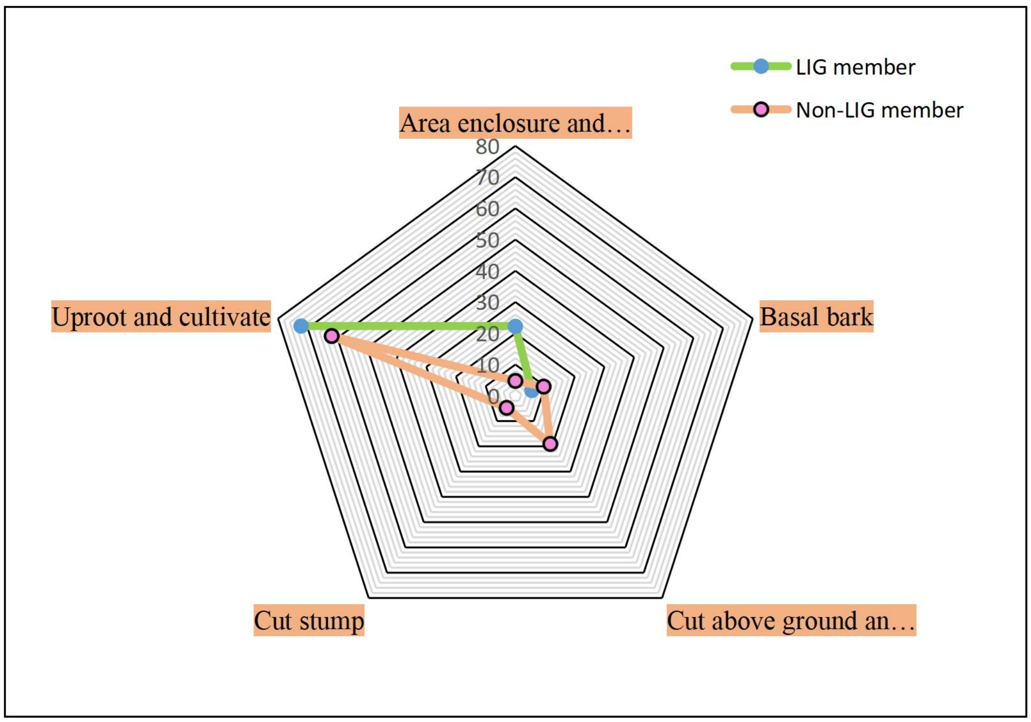


Figure 4. 6: Most preferred Control SLM practices

The LIG members perceived that applying chemicals on the cut stumps of *P. juliflora* to prevent re-growth might have adverse environmental and health impacts.

They also thought that the remaining stumps after the treatment would render the land unproductive since it would be costly to uproot the stumps before cultivating on the land. Likewise, LIG members acknowledged that they had limited knowledge of how to apply the chemicals making chemical treatments the least desired ones (figure 4.1.3). It is interesting, however, that basal bark treatment, which also entails the use of chemicals, was preferred by some LIG members.

4.1.4. Re-ranking of preferred SLM practices

Respondents were allowed to change their ranking of SLM practices from the most to the least preferred for continuous use. Assessing the number of changes made gave insight into the level of indecisiveness between the groups. It was assumed that the fewer changes made in ranking practices, the higher the confidence level in respondents' ideologies. In two of the three SLM categories (control and prevention), the non-LIG members made more changes than the LIG members (an average of 6 and 10 against 5 and 4, respectively (Figure 4. 7). The least number of changes were made for EDRR practices where none of the LIG members made any change.

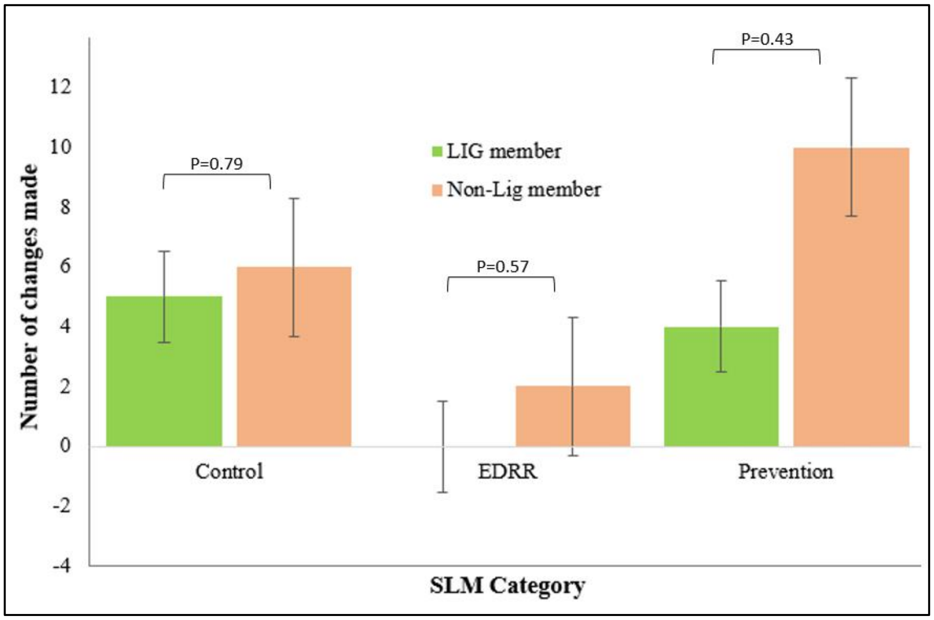


Figure 4. 7: Difference in the number of changes in ranking control (left), EDRR (center), and prevention (right) practices between the LIGs and the Non-LIGs. The vertical lines through the bar plots are error bars illustrating the data variability around the mean.

4.1.5. The Role of stakeholder-led participatory processes on SLM selection and implementation

This section discusses the above-highlighted findings of the first objective in light of existing literature. The results of this study indicate a statistically significant difference ($p<0.05$) between the LIG and non-LIG members in their perceptions of the need to manage invasion. Respondents involved in the participatory process appreciated the need and urgency to manage invasion compared to respondents excluded in the participatory process. Likewise, the LIG process enhanced the knowledge of the invasion impacts, making LIG members acknowledge and emphasize the urgency and need to manage the invasion. This finding supports those of de Graaf *et al.* (2008), who concluded that training land users shapes their intrinsic value for conserving their environment, motivating them to implement SLM practices to improve environmental performance (de Graaf *et al.* 2008) . This proposition is evident in that almost twice as many LIG members as non-LIG members strongly agree on the need to manage the spread of *P. juliflora*. The LIG process, therefore, seems to have enhanced the level of knowledge on the impacts of invasion and urgency for conservation, thus informing this preference.

To effectively evaluate the motivation of land users in implementing SLM practices, it is essential to focus the evaluation on the three sustainability dimensions: environmental, economic, and social (Schwilch *et al.*, 2012) . The findings of this study revealed that all three sustainability dimensions motivated both the LIG and non-LIG members to implement SLM practices, the economic dimension being the primary selection criterion (Bagavathiannan *et al.*, 2019b; Epanchin-Niell *et al.*, 2010; Shackleton *et al.*, 2016) . For instance, respondents perceived that all the three most preferred control practices (uproot and cultivate, enclosure and reseeding, and cutting below ground with reseeding) have potential economic benefits, pointing to the significance of financial incentives in shaping land users' decisions in managing invasion. The study observed that prospects for economic gains are the primary determinants of whether land users will continue implementing SLM practices to manage invasion. Thus, benefits derived from management efforts are likely to incentivize land users to invest and engage in environmental management (Nkomoki *et al.*, 2018) . However, comparing the two respondent categories based on their SLM preferences, it was noted that the non-LIG members were more driven by the economic dimension than the LIG members. Being the only group that preferred control by utilization through charcoal burning -which is a significant income source from the use of *P. juliflora*- the non-LIG members demonstrated a tendency to seek economic gains from cutting *P. juliflora* above the ground for charcoal production. While this practice is associated with financial gains, it promotes invasion progression through coppicing, which renders it unsustainable in managing the spread of *P. juliflora*. Further, previous studies (Eco *et al.*, 2015; Wakie, Hoag, *et al.*, 2016) have confirmed that utilization of *P. juliflora* creates overdependence on the species, resulting in conflicts of interest on the need to manage it.

The acknowledgment by LIG members that community members may not prefer certain SLM practices such as quarantines, on the basis that they are incompatible with their sociocultural norms of pastoralism, clearly indicates that land users' decisions to manage land are firmly embedded in their culturally defined rules and practices (Bagavathiannan *et al.*, 2019; Kasimbazi, 2017; Shackleton *et al.*, 2016). For enhanced ownership and continued implementation of SLM practices, it is imperative to incline management practices within acceptable standards provided by sociocultural institutions such as beliefs, lifestyles, and values.

Apart from the respondents' motivation to implement SLM practices, their decision to continually use them depends on the perceived effectiveness of the practices in meeting the intended goals (Saguye 2017) . The findings also illustrate that strict measures that limit immediate benefits are likely to be rejected by land users, especially those not well informed on the practical pros and cons of such practices. The lack of sufficient knowledge impedes the implementation of effective SLM practices, as evidenced by the respondents' disregard for technological advancements in invasion management. Despite their potential effectiveness and economic efficiencies in controlling the spread of invasion, a lack of knowledge on applying chemical, biological, and technological innovation in managing invasive species may impede their application by land users (Martinez *et al.*, 2020).

Besides the lack of capacity building, respondents were noted to select practices that integrate control and rehabilitation approaches, such as clearance and reseeding, rather than a single approach, like basal bark treatment alone. Integrating multiple practices strengthens their performance as the limitations of one practice are likely to be compensated by the strength of the other (USDA, 2021). Therefore, it is crucial to prioritize a combination of compatible practices to optimize their strengths and enhance their uptake by land users.

Finally, the participatory process likely stabilized the LIG members' perceptions, as evidenced by the consistency of their ranking of sustainable land management practices. This contrasts with uncertainties of non-LIG members' judgments as indicated by the changes they made while ranking SLM practices. This finding implies that the acquisition of evidenced-based knowledge shapes land users' opinions of SLM practices, stabilizing their perceptions of the SLM's strengths and weaknesses.

4.2. Spatio-temporal invasion trajectories of *P. juliflora* cover and spatial occurrence of land management decisions.

This section addressed the second objective. First, the results of the trajectory categories are explained, followed by results on spatial autocorrelation giving evidence as to whether the trajectories of *P. juliflora* are significantly clustered. The section also presents the drivers' results that influence land users' decisions in managing invasion, which is reflected in the observed trajectory categories. Finally, the section also discusses the findings in the context of the existing body of knowledge.

This section begins with findings on the trajectory categories that were significant for the study, followed by results on spatial autocorrelation giving evidence as to whether the trajectories of *P. juliflora* are significantly clustered. It then presents findings on drivers to land users' decisions in managing invasion, which is reflected in the observed trajectory categories. Finally, we conclude by discussing this objective's results and placing them in context with previous research findings.

4.2.1. Spatial-temporal trajectories of P. juliflora cover

The assessment of land cover data revealed 32 trajectories of *P. juliflora* invasion (i.e., distinct series/successions of the absence and presence of *P. juliflora* between 1988 and 2016).

Table 4. 1: Spatial temporal trends of *P. juliflora* cover.

	Category 1: A systematic adoption and implementation of SLM practices						**Area (Ha)**	**Area (%)**
	Pixel count	**1988**	**1995**	**2002**	**2009**	**2016**		
1	675	1	0	0	0	0	61	55
2	176	1	1	0	0	0	16	15
3	175	1	1	1	0	0	16	15
4	192	1	1	1	1	0	17	15
	Total area						**110**	**2**
	Category 2: The adoption but subsequent abandonment of SLM practices							

	Pixel count	1988	1995	2002	2009	2016		
5	1141	1	0	0	1	1	103	35
6	520	1	0	0	0	1	47	16
7	1049	1	0	1	1	1	94	32
8	301	1	1	0	1	1	27	9
9	193	1	1	1	0	1	17	6
10	85	1	1	0	0	1	8	3
		Total area					**296**	**4**
	Category 3: No attempt to adopt and implement SLM practices							
	Pixel count	1988	1995	2002	2009	2016		
11	45187	0	0	0	1	1	4067	64
12	20991	0	0	1	1	1	1889	30
13	4142	0	1	1	1	1	373	6
		Total area					**6329**	**94**

Spatial and temporal trends in the invasion trajectory of *P. juliflora* can be represented by the colors green (zero) and red (one), indicating the absence and presence of the species in a specific census year. The "Pixel Count" refers to the number of 30m-by-30-m pixels associated with a particular trajectory within the study area. According to calculations by the author using data from Mbaabu *et al.* (2019), the most extensive trajectory (trajectory no. 11) covers an area of 4067 km^2.

While some of them have small spatial coverage, others are inconclusive in terms of their invasion trends. Therefore, out of the 32 trajectories representing the presence and absence of *P. juliflora*, the study selected 13 relevant trajectories (Table 4.1) assigned to 3 categories that represent land users' decisions to manage invasion by implementing SLM practices. They include 1) systematic adoption and implementation of land management practices indicating successful continuous management; 2) adoption and subsequent abandonment of land management practices, indicating the uptake of management practices but the failure to use them in the long run; and 3) no attempt to adopt and implement land management practices.

Category 1: Systematic adoption and implementation of land management practices:

This specific category comprises four trajectories and encompasses the smallest spatial coverage, accounting for only 110 hectares (2% of the total area under consideration). The initial successful clearance, covering 61 hectares (55%) within this category, took place between 1988 and 1995. Trajectory 4 reveals that in more recent years (between 2009 and 2016), only a few areas measuring 17 hectares experienced the long-term clearing of *Prosopis cover* (Table 4.1).

Category 2: Adoption and Subsequent Abandonment of land Management Practices:

This category only accounts for only 4% of the assessed area and consists of 6 trajectories. Within Category 2, approximately 244 ha (82%) were initially cleared between 1988 and 1995 and later experienced re-invasion at different timeframes (Trajectory 4,5 and 6 as shown in Table 4.1). Between the year 1995 and the year 2002, about half (44%) of trajectory Category 2 (Trajectory numbers 5 and 9) were cleared (Table 2).

Category 3: No Attempt to Adopt and Implement Land Management Practices:

This is the most prevalent trajectory category in the study area, despite consisting of only three trajectories. Trajectory 13 reveals that, although the invasion of *P. juliflora* was slow in the earlier years (between the years 1988 and 1995), it eventually invaded 373 ha of the considered land, surpassing the total area of continuously adopted and implemented management practices (Category 1) for the entire study period. The invasion rate then increased more than fourfold in the subsequent 7-year period (between 1995 and 2002), covering 1889 ha. Furthermore, the invasion rate doubled in the following 7-year period, as indicated by Trajectory 11, which covers the largest area of 4067 ha. When comparing Trajectories 11, 8, and 5 within Category 2, it becomes evident that a significant wave of re-invasion took place between 2002 and 2009. This period also witnessed a considerable clearance of *Prosopis*, which occurred approximately between 1995 and 2009, followed by a subsequent re-invasion, as depicted by trajectory number 11.

4.2.2. Spatial distribution of trajectory categories

The moran's I statistics (Figure 4.8) illustrate that the three categories of invasion trajectories are spatially clustered ($I > 0$). This is supported by the significant evidence ($p<0.01$) to reject the null hypothesis, as there is less than a 1% (z-score >2.58) chance that the trajectory categories are randomly distributed. Moran's I scatter plot illustrates that weights assigned to similar trajectory values tend to cluster spatially. Hence, the spatial distribution of trajectory categories cannot be solely attributed to chance, indicating the influence of other explanatory variables. Subsequently, the study described the spatial occurrence of trajectory categories in relation to specific landscape features.

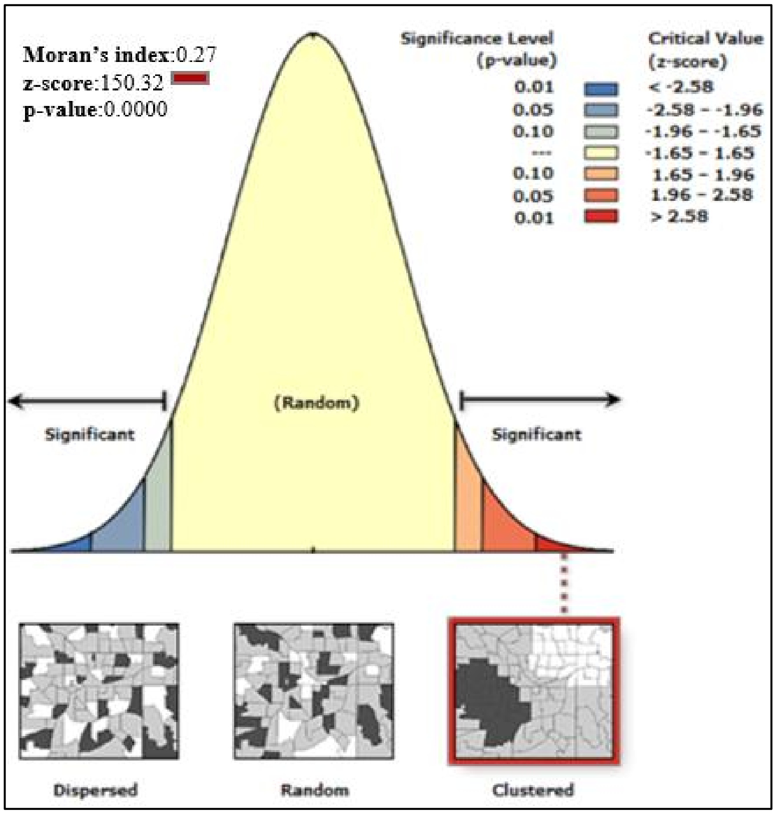


Figure 4. 8: The spatial autocorrelation graph (right) illustrates the spatial autocorrelation among the three trajectory categories

4.2.3. The relationship between trajectory categories and landscape features

4.2.3.1. Distance from the nearest river

In general, there is a decline in the coverage of the three categories as the distance to the river increases. However, Categories 1 and 2 are more prevalent within the first 800 meters from the nearest river, in comparison to trajectory Category 3. (Figure 4.9 and Map 4.1B). No clear pattern was detected between 800 and 1500 m from the closest river, while at a distance of >1500 m from a river, categories 1 and 2 are under-represented (Figure 4.9). Parcels located near rivers, which are typically expected to be cleared, were observed to be vulnerable to re-invasion, as indicated by the significant presence of Category 2 in close proximity to rivers.

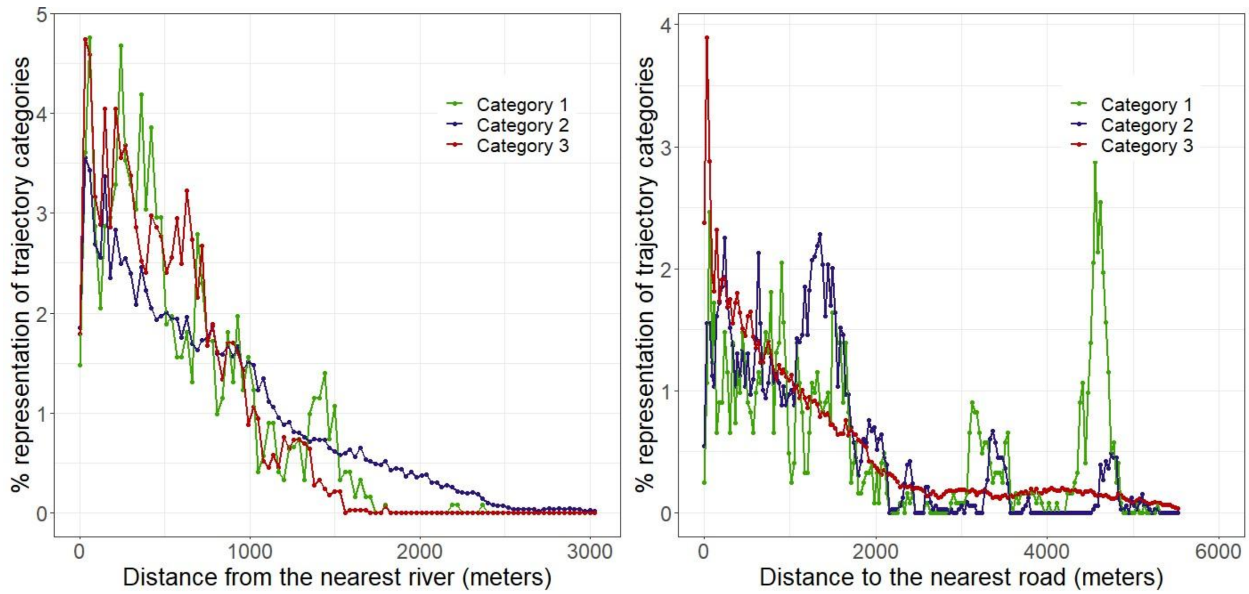
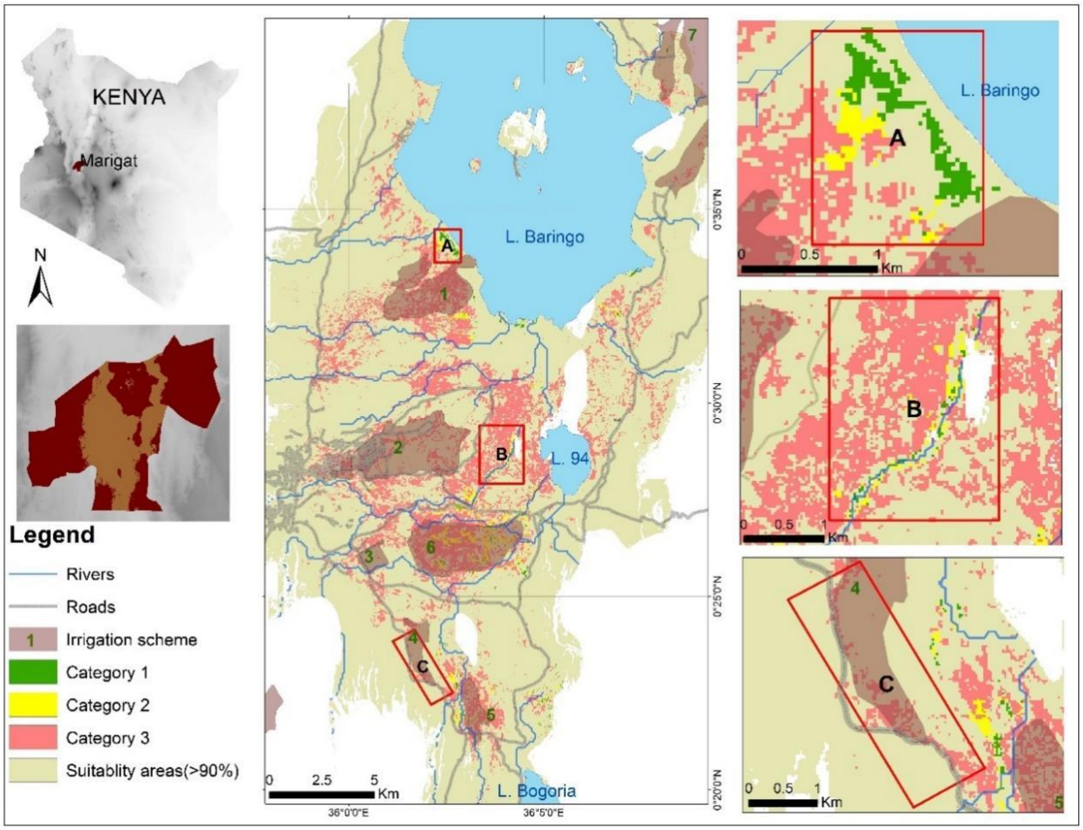


Figure 4. 9: The correlation between trajectory categories and their proximity to the nearest rivers and roads

4.2.3.2. Distance to the nearest road

The analysis reveals that Category 3 is disproportionately present within a 250 m distance from the nearest roads (Figure 4.9). However, its coverage gradually decreases beyond this distance, and it levels off at around 2800 m. Categories 1 and 2 display irregular distribution patterns along the roads. The majority of areas classified as Categories 1 and 2 are concentrated within the first 1700 m from the roads, whereas approximately 33% of Category 1 areas are situated beyond 3000 m from the roads. These areas correspond to the cultivated regions in the southwestern part of Lake Baringo (Map 4.1A).



Map 4. 1: The allocation of trajectory categories across 90% suitability areas is depicted in the main map, with specific focus on the shorelines of L. Baringo (A), along rivers (B), and roads (C).

4.2.3.3. Relationship between P. juliflora trajectories and land use and land cover

The initial clearance of *P. juliflora* between 1988 and 1995 led to the establishment of natural vegetation, which later underwent conversion into different land cover classes. Unlike grasslands and bare land, which were predominantly direct conversions from *P. juliflora*, areas under irrigated agriculture benefited from the establishment of natural vegetation that had replaced the initial *P. juliflora* cover (Figure 4.10). A significant portion of *Prosopis* cover was converted to bare land between 2002 and 2009, while the proportion of waterweeds doubled during the same period. Additionally, a small percentage (2%) of the *P. juliflora* cover in 2002 transitioned to water for the first time, with a portion of it likely being submerged *P. juliflora* trees in the expanding Lake Baringo.

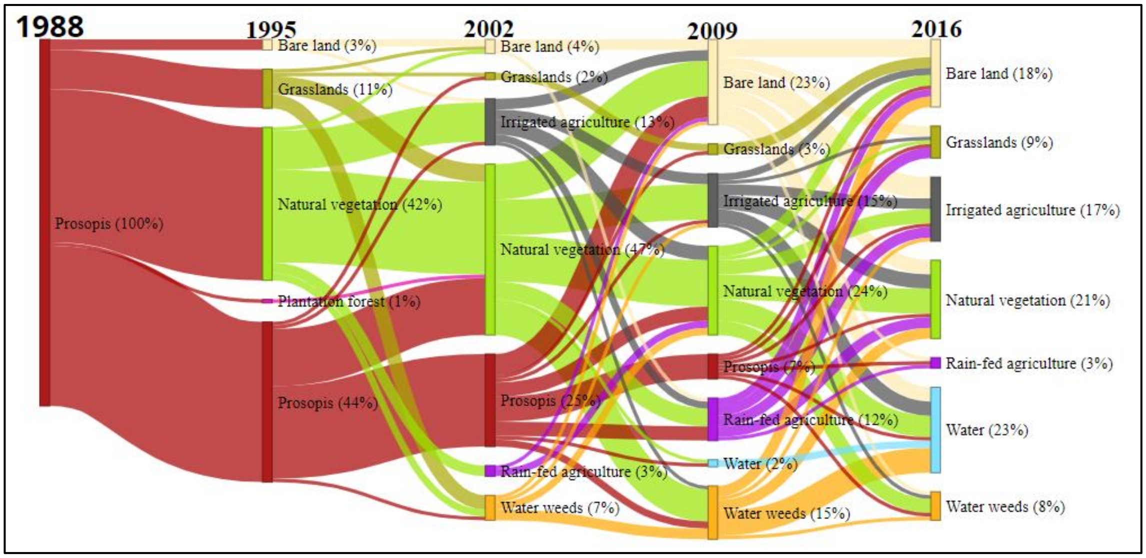


Figure 4. 10: The temporal variations in land cover within systematically cleared *P. juliflora* areas (trajectory Category 1).

In the re-invaded areas, the major clearance of *P. juliflora* occurred between 1995 and 2002, followed by the highest rate of re-invasion between 2009 and 2016 (Figure 4.11). This significant wave of re-invasion in 2009 primarily affected parcels categorized as grasslands, natural vegetation, rain-fed agriculture, irrigated agriculture, and waterweeds.

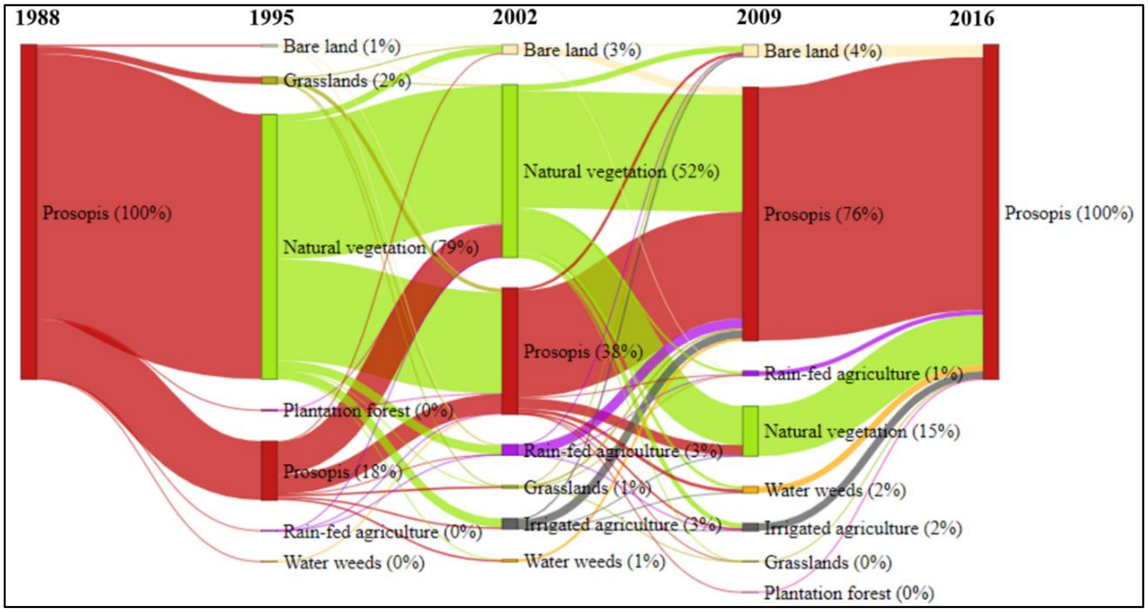


Figure 4. 11: The temporal changes in land cover the areas that underwent initial clearance of *P. juliflora* but later experienced re-invasion. (trajectory Category 2).

The areas constantly invaded since their initial invasion was first converted from different LULC classes between 1988 and 1995 (Figure 4.12). All the other parcels within Category 2 were first invaded in the subsequent 14 years, illustrating a rapid progression of *P. juliflora* cover between 2002 and 2009. The results also show that the *P. juliflora* invasion occurred in all LULC classes except water bodies (Figure 4.12).

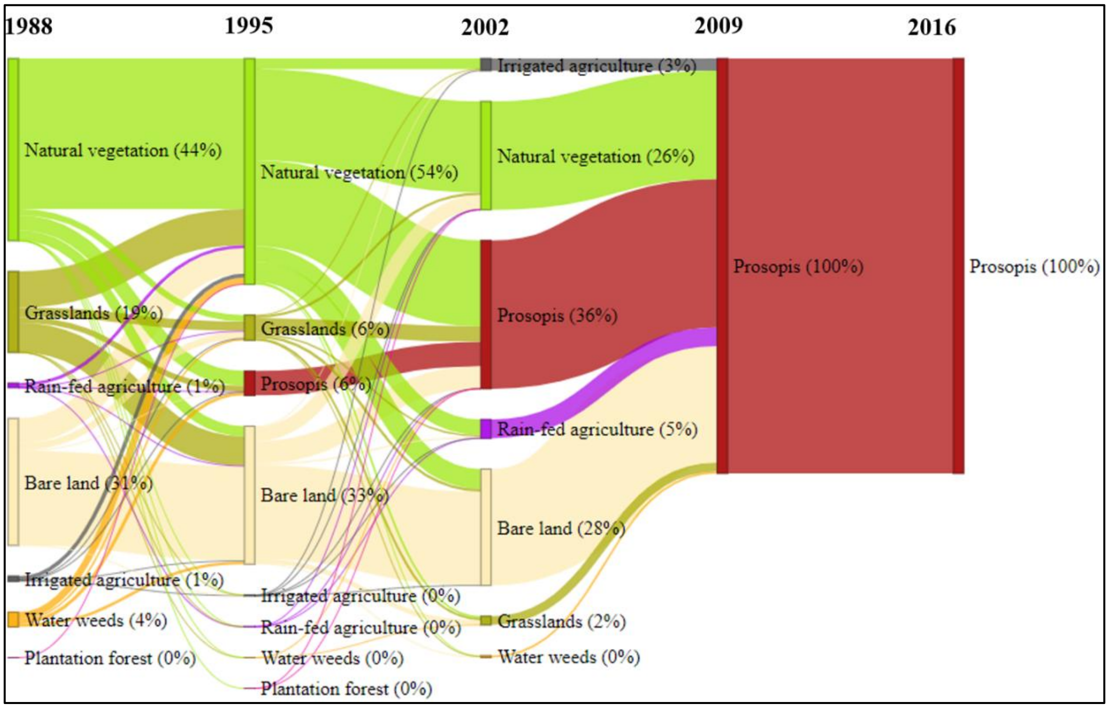


Figure 4. 12: The alterations in land cover over time within regions that have remained uncleared of *P. juliflora* since its initial invasion (trajectory Category 2).

4.2.3.4. Proximity to irrigation schemes

Contrary to expectations, our study reveals that only 15% of the areas that were consistently cleared are located within irrigation schemes (Figure 4.13). The areas that have been permanently cleared or cleared and re-invaded (Categories 1 and 2) are sparsely distributed within the Perkerra irrigation scheme, which is the oldest scheme in the study area (represented as number 2 in Map 4.1). However, these two categories are more prevalent in the Loboi and Eldume irrigation schemes (represented as numbers 5 and 6 in Map 4.1). Interestingly, both the Loboi and Eldume schemes are characterized by the presence of rivers or streams running through them. Specifically, a network of river tributaries intersects the boundaries of the Eldume irrigation scheme (number 6 in Map 4.1), which has the greatest share of Categories 1 and 2.

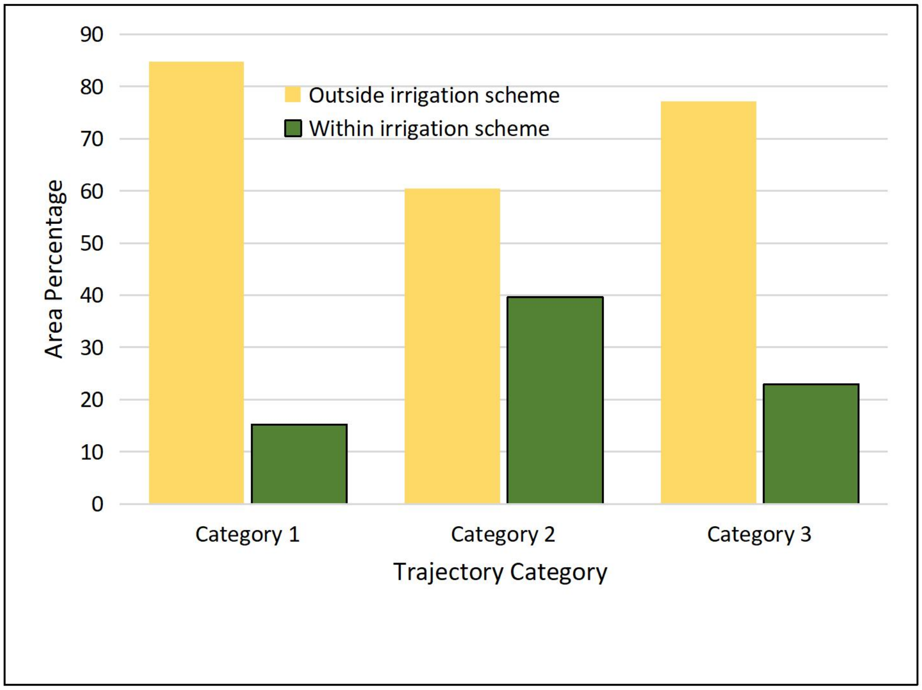


Figure 4. 13: Distribution of trajectory categories concerning irrigation schemes.

Approximately 40% of the areas that experienced clearance and subsequent re-invasion (Category 2) are located within irrigation schemes (Fig. 4.14). Furthermore, while only a quarter of the constantly invaded areas (Category 3) are situated within irrigation schemes, this category covers around 31% of the total area occupied by the irrigation schemes.

4.2.4. Spatial-temporal invasion trajectories and associated spatial drivers of management decisions.

An analysis of the spatial-temporal pattern of *P. juliflora* for the past 28 years illustrates *Prosopis* invasion trajectories that can be related to land users' management decisions and are linked to the spatial occurrence of landscape features. Both continuous clearances and initial clearance with subsequent reinvasion majorly occurred close to water bodies. However, no evidence was found for implementing land management practices on most of the parcels invaded by *Prosopis,* including communally owned land along roads. The section that follows discusses the findings of objective 2 on the spatiotemporal trends of *P. juliflora* and their relation to spatial drivers of land management decisions.

4.2.4.1. Temporal trends of P. juliflora invasion trajectories

The findings of the study indicate that once *P. juliflora* is established, it does not easily disappear on its own. Any changes observed in the cover of *P. juliflora* can be attributed to land users' decisions to adopt or not implement management practices. Therefore, invasion trajectories serve as a monitoring system for land users' management decisions and actions over time (Liu & Cai, 2012) . The use of reclassified land use and land cover (LULC) maps ensured the quality and credibility of the findings while also saving resources by avoiding duplicate data collection, management, and classification (Hsiao & Cheng, 2016). Nevertheless, while the examination of *P. juliflora* cover trajectories allowed us to identify the intricate non-linear changes in invasion patterns (Liu & Cai, 2012), analysis of LULC data over a 7-year period may not have captured shorter cycles of land management.

The study revealed a gradual decrease in the area covered by Category 1 (continuous implementation of land management practices) and a significant increase in Category 3 (no attempt to adopt or implement management practices) over time. This indicates that the sustainable management of *P. juliflora* invasion by land users in the study area is ineffective (Mbaabu *et al.*, 2019) . The uptake of management practices for *P. juliflora* occurred in the early stages of its invasion but became less likely as time progressed. Probably, land users were overwhelmed by the advancing densities and increasing sizes of *P. juliflora* trees which made the tree more difficult and costly to control (Pérez-Serrano *et al.*, 2021; Shackleton *et al.*, 2016a) . This highlights the significance of Early Detection and Rapid Response (EDRR) as they are cost-effective and have a higher likelihood of adoption by land users compared to the removal of mature *P. juliflora* trees at later stages of invasion (Kariyawasam *et al.*, 2021) . Accordingly, mapping *P. juliflora* trajectories and evaluating their associated drivers need to be established into land management planning tools that prioritize EDRR efforts (Manzoor *et al.*, 2021).

The study also found that the initial clearance of *P. juliflora* coincided with a major drought in the Marigat Sub-County, during which land users resorted to charcoal production using *P. juliflora* as a raw material for economic survival (Kosonei *et al.*, 2017). However, to effectively manage *P. juliflora*, the removal of above-ground *Prosopis* biomass should be integrated with uprooting the rootstocks, as the species tends to resprout rapidly from the cut rootstocks. (Dzikiti *et al.*, 2013). During the same period, the demand for produced maize seeds also witnessed an increase; coupled with the availability of a ready seed market through seed companies, agricultural activities expanded and hence increased management of *P. juliflora,* especially on farmlands (Mbaabu, Ng, Schaffner, Gichaba, *et al.*, 2019b). Nonetheless, a decline in the demand for maize seeds, as observed in 1995, led to the abandonment of agricultural activities and subsequently facilitated re-invasion by *P. juliflora*. This might explain the wave of invasion observed during this period, which is also reflected in the trajectories.

4.2.4.2. The relationship between P. juliflora invasion trajectories with spatial features

The relation of Spatio-temporal trajectories with landscape features improved the explanatory potential of our mapping process. Previous practical experience or empirical studies were necessary to select relevant variables. For instance, the selection of rivers, roads, and LULC was informed by (Dzikiti *et al.* 2013; Eckert *et al.*, 2020; Mbaabu, Ng, Schaffner, Gichaba, *et al.*, 2019) who confirmed that proximity to such spatial features might influence invasion patterns. According to a previous study (Schirpke *et al.*, 2020) , the overlay of functional spatial units is significant in assessing a combined effect of drivers on LULC trajectories.

According to our findings, a vast majority of continuous clearances (Category 1) occurred within 800 meters of the rivers within which *P. juliflora* was often cleared to pave the way for cultivation (Mbaabu, Ng, Schaffner, Gichaba, *et al.*, 2019b) . This indicates that land users preferentially cleared land along riverine corridors where water was accessible to enable them to irrigate their crops, especially during drought seasons. Hence, the presence of essential resources, such as water in this particular scenario, serves as a major driving force for agricultural endeavours and, indirectly, the adoption of *P. juliflora* management practices (Wiesmann *et al.*, 2011).

Despite playing a crucial role in the clearance of *P. juliflora*, agricultural lands were still susceptible to invasion. According to (Kariyawasam *et al.*, 2021) , agricultural lands are particularly vulnerable to invasion, especially when cultivation activities are interrupted or weakened. This makes them vulnerable to re-invasion. In this research, a high proportion of irrigation schemes were re-invaded, with very few patches being constantly cleared despite their economic significance to land users. However, the observed differences in the distribution of trajectories among irrigation schemes may be attributed to the different management practices as well as different times of establishment among the schemes. On the one hand, the Perkerra irrigation scheme began operating in early 1960s (Nadeiwa & Koring, 2017), before the challenges posed by *P. juliflora* invasion were acknowledged and when local land users had limited experience on how to manage invasions.

This led to a delay in implementing preventive measures or executing early detection and rapid response (EDRR) practices. As a result, the invaded lands were eventually abandoned due to the significant costs associated with reclaiming them. On the other hand, Eldume and Loboi irrigation schemes (5 and 6 in Map 4.1) were established in later years through initiatives by farmers who had benefited from hard lessons learned in Perkerra. Their motivation to keep their farms free of *P. juliflora* is thus illustrated by a higher occurrence of Category 1 (constantly cleared) in these two schemes than in Perkerra (Fig. 4.2. 3).

The lessons learned from the different Spatio-temporal patterns in Perkerra, Loboi, and Eldume echo the finding of previous studies (Gill *et al.* 2018; Kariyawasam *et al.* 2021; Shackleton *et al.* 2016; The National Invasive Species Council 2012) which emphasize the importance of EDRR, timely information and continuous implementation of management practices. They also highlight the significance of establishing efficient rural advisory systems that assist land users in implementing an effective Early Detection and Rapid Response (EDRR) system. Such systems aid in making timely management decisions and adopting sustainable practices to preserve the productive potential of the land. In fact, a significant portion of the abandoned irrigation schemes had become unproductive due to salinization of land (Mbaabu, Ng, Schaffner, Gichaba, *et al.*, 2019b) , lowering returns on investment and limiting land users' motivation to invest in land management practices (Kropf *et al.*, 2020).

The concentration of Category 3 along roads reflects two distinct trends: (a) footpaths, roads, livestock routes, and trails are dispersal pathways for *P. juliflora* (del-Val *et al.* 2015; Eckert *et al.* 2020; Sintayehu *et al.* 2020) , and (b) land users have a low incentive to clear invasive species from such shared resources where no one is personally held accountable for their management. This indicates that land users' decision to manage land from invasion depends on the expectations to derive benefits that compensate for their management investments (Bagavathiannan *et al.*, 2019a; de Graaff *et al.*, 2008; Epanchin-Niell *et al.*, 2010).

Based on the analysis of various *P. juliflora* cover trajectory categories, we have observed that there are no clear transitions between land use/land cover (LULC) types and *P. juliflora* invasion. In several cases, transitions occur between different LULC classes before *P. juliflora* invasion takes place. Consequently, management strategies that solely target one specific type of change, such as the transition from *P. juliflora* to cultivation, would likely miss the intended objective.

4.2.4.3. *The implications for landscape-scale land management*

These findings consistent with earlier research (Gill *et al.*, 2018; Shackleton *et al.*, 2016a), highlighting the significant influence of economic incentives in motivating land users to persistently address the invasion of *P. juliflora*. These findings indicate that ongoing clearance of *P. juliflora* is more likely in areas where the benefits sufficiently compensate land users for their management endeavors. Thus, continuous clearance of *P. juliflora* is more probable on parcels where the benefits adequately compensate land users for their management efforts. (Cowie *et al.*, 2018) confirm that agricultural lands, where economic returns are expected, are still vulnerable to invasion worldwide. This suggests that effectively managing invasive alien species (IAS) requires a landscape-level approach rather than focusing solely on individual parcels. Invasions tend to occur rapidly and affect large areas, impacting numerous individuals. Therefore, a coordinated and collective approach by land users at the landscape level (Bagavathiannan *et al.,* 2019b) is necessary for effective management. is essential for successful management. To accomplish this, it is important to investigate landscape invasion patterns and evaluate the drivers associated with them.

The results of the study indicate that analyzing the spatio-temporal trajectories of invasive alien species (IAS) can offer valuable insights into the dynamics of invasions and the factors driving them. This information can then inform land management decisions that are specifically tailored to the spatial context. The identified invasion trends highlight that the current management efforts are inadequate and restricted to small areas, where land users anticipate receiving financial benefits, such as access to agricultural land, in return for their efforts (Bagavathiannan *et al.*, 2019a; Gill *et al.*, 2018). The management of *P. juliflora* is almost absent in areas where no one is personally held accountable (such as along roadside corridors and communal grazing land), as well as in areas whose perceived value does not justify the investment, even though the neglected parcels generally become vulnerable to invasion and are often neighbouring more valuable land within which land users invest resources to manage. The presence of neglected parcels poses a challenge to the sustainable management of invasive alien species (IAS) since these parcels serve as sources of propagules for neighboring managed parcels (Epanchin-Niell *et al.*, 2010) . As previously mentioned, this underscores the importance of collective management of *P. juliflora* at the landscape level rather than focusing on individual plots.

Finally, previous studies (Bagavathiannan *et al.*, 2019a; Kropf *et al.*, 2020; Niemiec *et al.*, 2020) confirm that social cooperation among community members is key to successful management at the landscape level. However, owing to conflicting interests and motivations among land users, achieving collective actions in IAS management remains a social dilemma (Epanchin-Niell *et al.*, 2010). Considering the documented rates of success and the advantages associated with biological control methods, studies (Bagavathiannan *et al.*, 2019a; Zimmermann & Maennling, 2007) recommended the application of biological control approaches as an alternative to foster the achievement of a coordinated management of IAS at the landscape level. This is because biological agents are self-sustaining and they also operate independently of stakeholder management actions (Bagavathiannan *et al.*, 2019a).

4.3. Drivers to land users' uptake and continued use of SLM practices.

Findings in the previous section (chapter 4.2) focus on the spatial-temporal trajectories and their association with landscape features. While it identifies land users' decision to implement SLM practices as being key to managing invasion, it acknowledges the need to explicitly evaluate the underlying drivers for land users' management decisions reflected in the identified trajectories. This requires assessing drivers spatially contextualized to the respective trajectories to inform spatially explicit management approaches.

Based on identified spatial-temporal trajectories of *P. juliflora,* this section presents findings of the analysis on the drivers of land users' uptake and continued use of SLM practices aimed at managing *P. juliflora* invasion and identifies potential entry points for the continued implementation of SLM practices. Targeting the Kenya National *Prosopis* Strategy this section also highlights critical lessons for the sustainable implementation of the national and sub-national strategies of IAS management.

4.3.1. Categories of drivers influencing land management decisions

This study's results identified multi-dimensional drivers of land users' decisions to continuously implement SLM practices for the management of IAS. These were categorized into sociocultural, environmental, economic, and political drivers based on their order of significance (Figure 4.14). While socio-cultural drivers were the most mentioned, political drivers were mentioned infrequently and were not identified as prominent factors influencing management decisions.

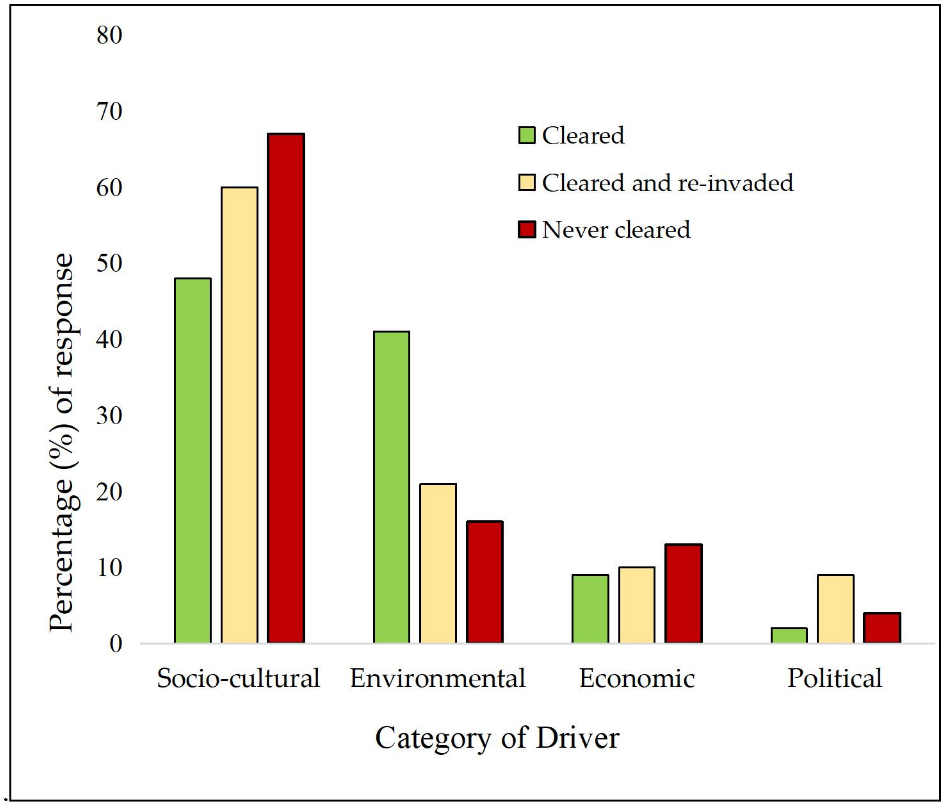


Figure 4. 14: A chart showing the drivers of land users' land management decisions.

Below are findings on how the identified drivers within these four categories influence land management decisions.

4.3.2. Executing land management decisions for invasion management.

4.3.2.1. Intensive land management practices

Intensive management practices like cultivation, planting perennial plants such as fruit trees, irrigation, and crop rotation (Figure 4.15), promote constant land management to ensure that it is not left idle and exposed to invasion. These were perceived as key drivers that promote continuous SLM implementation, especially on farmlands.

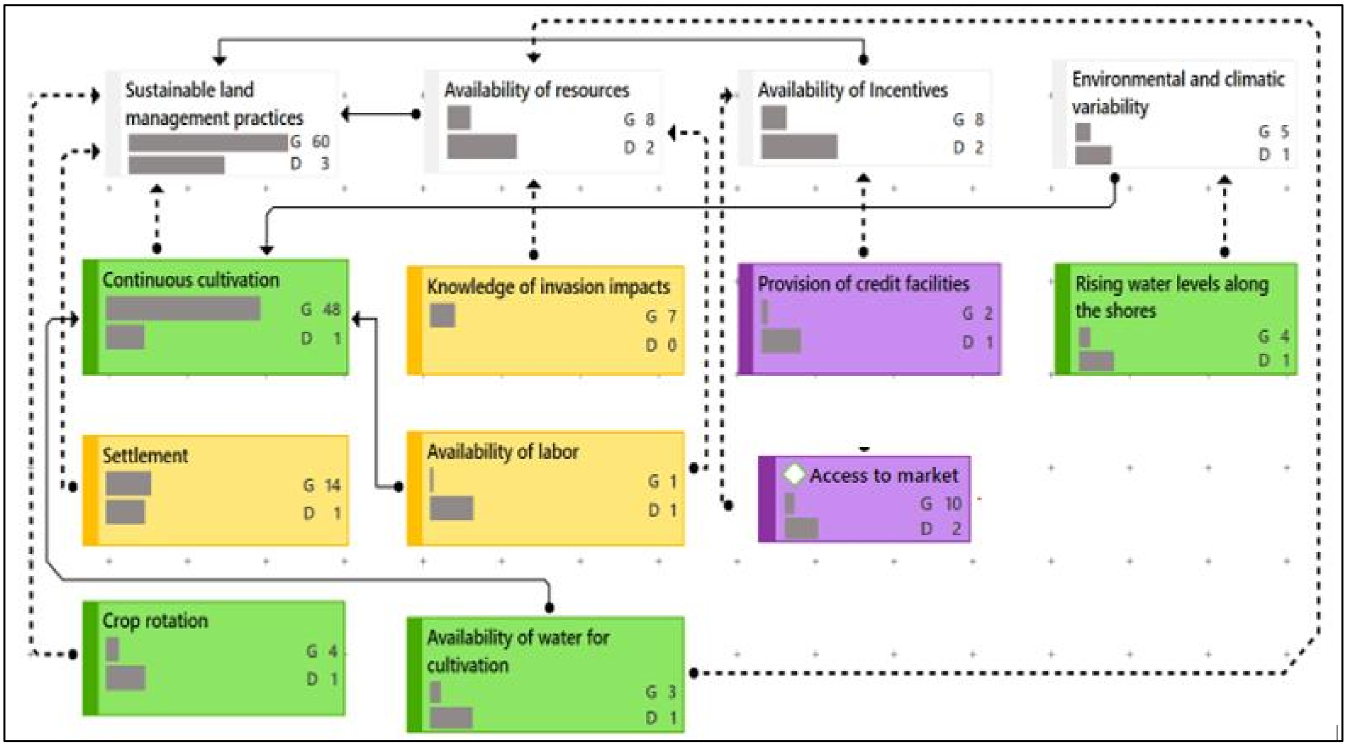


Figure 4. 15: The drivers contributing to continuous clearance are categorized into three groups: social-cultural (represented by yellow), environmental (represented by green), and economic (represented by purple). The arrows indicate the direction of influence between the drivers. The metrics used to measure the strength of these drivers are Groundedness (G), which represents the number of linked quotations, and Density (D), which represents the number of linked codes. The length of the bars within each box reflects the frequency of G and D, indicating their significance.

It was observed that continuous cultivation lowers the chances of (re-) invasion since land users are keen on retaining their farms. Yet, implementing intensive land management practices requires the availability of resources like finances, labor, water for irrigation, knowledge of the potential effects of *P. juliflora*, and skills to manage it.

Apart from agricultural practices, proximity to settlements was perceived to promote continuous clearance of *P. juliflora*. Land users were perceived to be committed to enhancing the safety of their residential homes by regular clearance of

P. juliflora thickets which were reported to harbor thieves and dangerous wild animals. Pastoralism makes it challenging to map settlement areas, but physical visits to the trajectory areas, coupled with responses from interviewees, confirmed settlements as a driving factor for constant clearance. Indeed, our analysis confirms this finding as continuous cultivation and proximity to settlement are co-occurring (c-index=0.05)

4.3.2.2. Availability of incentives and resources

Respondents perceived incentives as a key tool in promoting land users' engagement in invasion management. They reported that land users are unlikely to engage in SLM implementation in the absence of incentives to do so and where benefits might not be guaranteed. The availability of affordable credit facilities, access to a ready market, and better pricing of farm produce (Figure 4.15) avail the means required for implementing SLM practices on cropland. For instance, farmer engagement by the National Irrigation Board (NIB) through contractual farming of maize seeds promotes land users' engagement in agricultural activities due to the availability of a ready market (personal interviews with area chiefs). The NIB also offers extension services and credit facilities to farmers. These promote the clearance of *P. juliflora* on croplands, especially along the shorelines of lakes and rivers with a constant supply of water to sustain year-round irrigation. This feedback is supported by the fact that the majority of the cleared *P. juliflora* cover (62%) was converted into irrigated agriculture, and 88% of irrigated parcels were maintained under the same use (Figure 4.16).

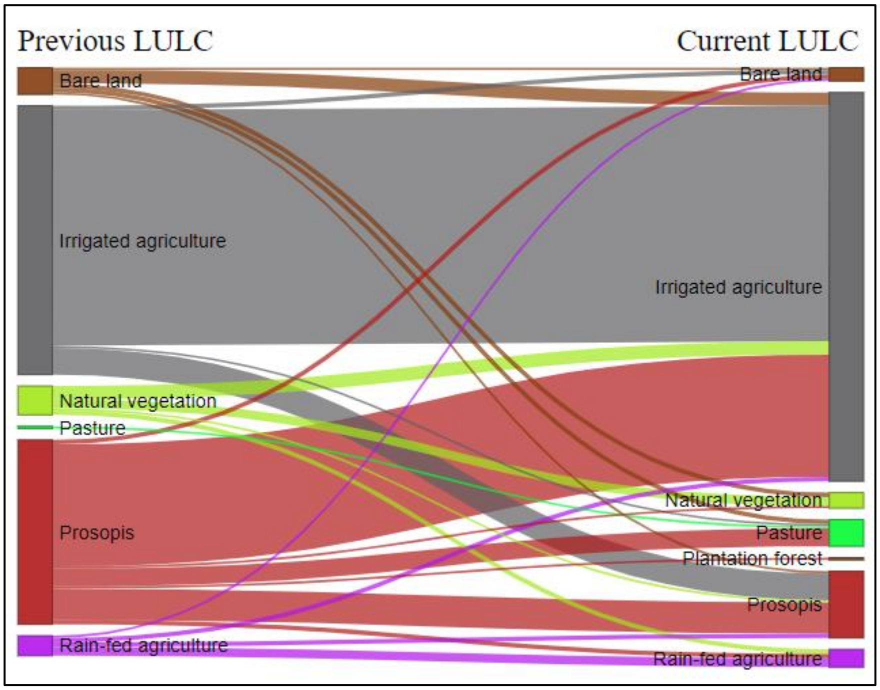


Figure 4. 16: Sankey chart of transitions of LULC classes within respondents' parcels. Source: Survey data

4.3.2.3. Knowledge of impacts and associated high cost of clearance

Respondents perceived that the timely knowledge of invasion impacts, the benefits of early management, as well as the significance of effective SLM implementation, are central to successful IAS management. An understanding of the implications of SLM practice adoption and implementation (or not) is determined by land users' past experiences. Therefore, land users with first-hand experience of the high clearance costs feared incurring similar expenses and were prompted to maintain their implementation of SLM practices to prevent re-invasion. Similarly, respondents originating from densely invaded areas and who clearly understood the implication of delayed response actions were keen to engage in managing *P. juliflora*, the perceived potential benefits from utilization notwithstanding. While knowledge about the high costs of managing invasion was acknowledged as a contributor to continuous invasion management, it is worth noting that only 9% of the interviewees confirmed knowledge of the impacts as a motivation to clear *P. juliflora,* compared to 56% of respondents who mentioned continuous cultivation as a driver for land users' implementation of SLM practices.

4.3.3. Drivers of abandonment or non-adoption of SLM practices

Socio-cultural factors were identified as the primary reasons for the failure to adopt and the abandonment of Sustainable Land Management (SLM) practices (Figure 4.17).

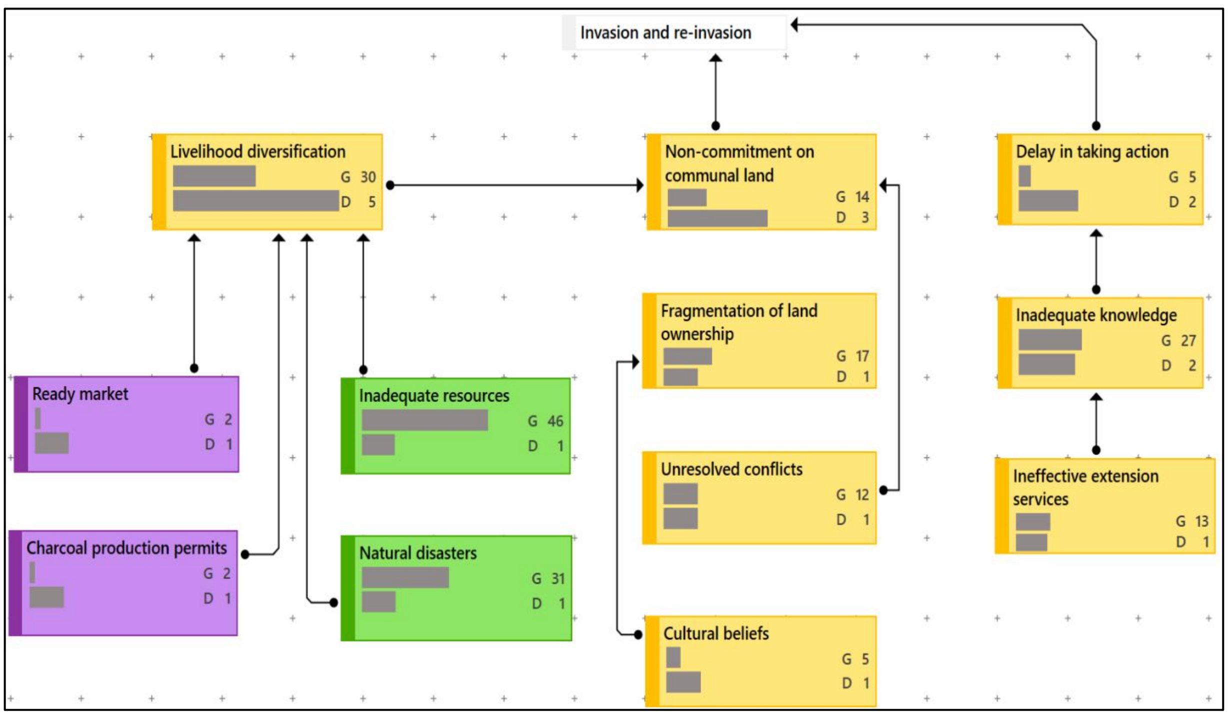


Figure 4. 17: The factors contributing to continuous invasion and re-invasion

are categorized into three groups: social-cultural (represented by yellow), environmental (represented by green), and economic (represented by purple). The arrows indicate the direction of influence between the drivers. The metrics used to measure the strength of these drivers are Groundedness (G), which represents the number of linked quotations, and Density (D), which represents the number of linked codes. The length of the bars within each box reflects the frequency of G and D, providing an indication of their significance.

According to 87% of the respondents, non-adoption or abandonment of SLM practices predominantly occurred on communally owned lands. Key drivers attributed to this were livelihood diversification, the prevailing customary land tenure system, and limited knowledge regarding invasive alien species (IAS) (Figure 4.17).

4.3.3.1. Diversification of livelihoods

Livelihood transformation from traditional pastoralism – as a result of loss of grazing land - to agriculture and charcoal production was perceived to lower land users' dependence on land resources. This, in turn, contributes to reducing land users' engagement in invasion management. Apart from the emergence of new livelihood opportunities, respondents also argued that the occurrence of natural disturbances like droughts and floods, coupled with the associated degradation of grazing land, promoted this livelihood transformation. Indeed, our analysis shows a co-occurrence of livelihood diversification with the above-the-ground cutting of *P. juliflora* for charcoal production (c-index=0.36) and drought (c-index=0.29).

The feedback from interviews showed that severe drought, especially in 1995, prompted local communities to seek alternative income sources through charcoal production, an activity that later contributed to coppicing of *P. juliflora*. The degradation of pasturelands by drought and heavy invasion was believed to accelerate the loss of livestock upon which pastoral communities depended. This forced them to seek alternative options to survive. The provision of licenses by the government for charcoal production and the availability of high market demand (c-index = 0.25), together with the widespread availability of *P. juliflora* trees during this time, was considered a strong incentive for charcoal production as a new source of livelihood. This vicious circle further lowered land users' dependence and motivation to manage communal grazing lands, which were consequently exposed to invasion (personal interviews, area chiefs, October 2019).

4.3.3.2. Ineffective land governance

Based on a majority (60%) of the respondents, this research found that ineffective land governance was evidenced by the fragmentation of parcels, unresolved land disputes, and the neglected management of communal lands. The traditional land acquisition process under the customary land tenure system provided guidelines for accessing communal land for private use in the form of farmlands or settlements. This approach bestowed absolute freedom upon men to claim and own unlimited parcels of land on the condition that they had a past claim on such parcels. As a result, the aged community members had ownership of many fragmented parcels, with limited capacity to manage them owing to their limited financial resources and labor. As a confirmation of this, the likelihood of croplands being invaded by *P. juliflora* increased with increasing distance from homesteads (Figure 4.19). This supports respondents' perceptions that land users with many fragmented parcels are likely to prioritize managing *P. juliflora* on the farms closest to their homesteads as the distant plots become vulnerable to invasion. The two explanatory drivers, 'distance from home' and 'ownership of many parcels also co-occurred (c-index= 0.09).

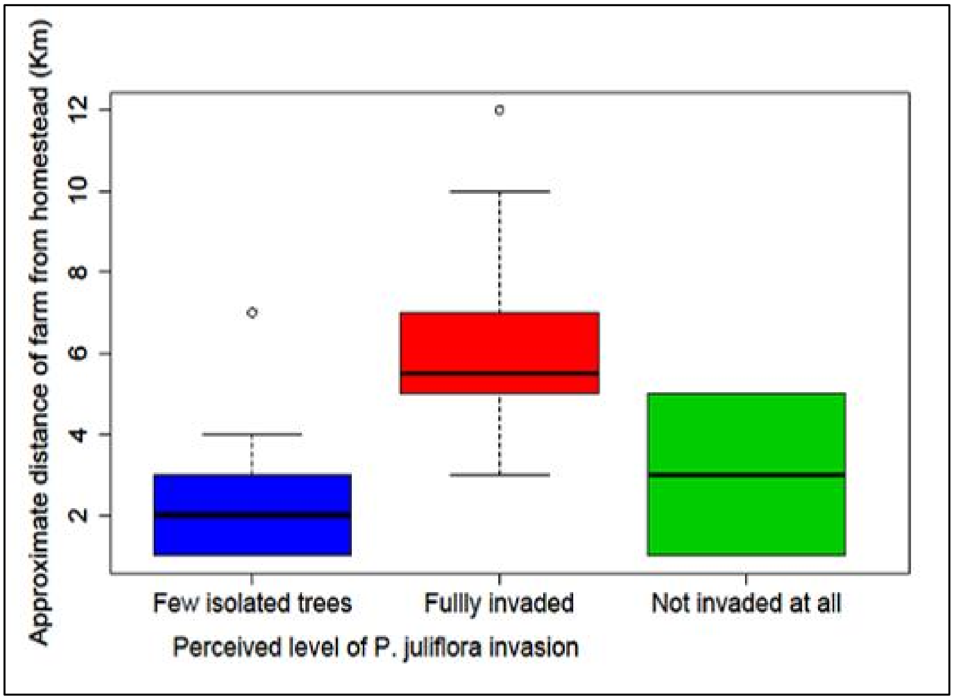


Figure 4. 18: The correlation between the level of *P. juliflora* invasion and the distance of farms from homesteads. In the graph, the boxes represent the median value (indicated by the thick line separating the box into two halves), while the lower and upper quartiles are depicted by the lower and upper borders of the boxes, respectively. The whiskers extending from the lower and upper quartile marks indicate scores that fall outside the middle 50% of the total scores. Additionally, any dots on the graph represent outliers.

In addition to the distance from homesteads, weak tenure rights enforcement by responsible institutions contributes to unresolved land disputes leading to the abandonment of land and subsequent invasion. Such conflicts were reported to remain unresolved for long periods as the concerned parties were rarely satisfied by decisions made by local authorities. Dragging land disputes for years led to a halt of all management activities, presenting a free pass for the *P. juliflora* invasion. Conflicts over communally owned lands and resources are most prominent in sparsely invaded sub-locations (c-index= 0.02). The feedback from interviews with the area chiefs indicated that livestock migration from densely to sparsely invaded communal grazing lands enhanced the invasion of the latter, resulting in conflicts over diminishing pastures.

4.3.3.3. Significance of timely management

Delayed and unreliable information about the potential impacts and invasion process of *P. juliflora* was perceived by 34% of respondents to delay the onset of land management efforts and promote the progression of IAS cover to dense levels where taking action demands more labor and finances. As a result, land users are discouraged from taking any action. The situation is aggravated by inappropriate information on suitable alternatives for managing invasion; land users' initial efforts to cut *P. juliflora* above the ground were misconceived to manage the spread, but instead, it favored coppicing and rapid spread.

Delay in understanding the actual impacts of *P. juliflora* strongly co-occurs with the respondents from the densely invaded sub-locations (c-index= 0.14), compared to those from sparsely invaded sub-locations (c-index= 0.01). It also co-occurs with advanced invasion (c-index= 0.22), indicating its contribution to the progressive invasion in the currently densely invaded areas. On the other hand, respondents from sparsely invaded sub-locations do not perceive delayed or unreliable knowledge as an obstacle to effective IAS management. Instead, they consider the perceived *P. juliflora* benefits (c-index=0.05) to adversely impact land users' willingness to adopt SLM practices for fear of losing the derived benefits, such as the source of income from charcoal production and provision of shade.

Respondents residing in heavily invaded sub-locations share a similar perception, although with a lower co-occurrence rate (c-index=0.02).

As previously mentioned, the limited implementation of effective land management practices stems from inadequate knowledge in this area. This situation was confirmed within the Perkerra irrigation scheme, where several land users have abandoned their agricultural land due to the loss of its productive potential. Respondents attributed the loss of productivity to poor farming practices resulting in salinization and waterlogging. This perception was confirmed during an interview with the National Irrigation Board's officer. Findings from interviews with land users also show that 8% of croplands owned by respondents were lost to *P. juliflora* invasion (Figure 4.16).

4.3.4. Spatial drivers influencing the adoption and persistent utilization of sustainable land management (SLM) practices.

Based on the above findings, this section discusses the results of objective two in the context of existing studies. The findings have illustrated that land users' decisions to adopt and implement SLM practices are reflected in invasion trajectories and are influenced by multi-dimensional socio-cultural, economic, environmental, and political drivers. Active land management, such as through continuous cultivation, was considered by respondents to be a key factor in enhancing invasion management. Even so, this depends on land users' ability to access resources as well as their motivation to engage in SLM implementation (Kropf *et al.*, 2020). Thus, the main drivers for effective SLM implementation are timely access to appropriate information on the invasion process and the provision of incentives, credit facilities, favorable market dynamics, and financial resources (Gill *et al.*, 2018; Niemiec *et al.*, 2020).

Unlike the enabling drivers, the negative drivers are diverse and numerous and therefore limit the performance of enabling drivers. There is, therefore, an urgency to effectively address the negative drivers if IAS is to be sustainably managed. Therefore, this chapter discusses the causal connections among negative drivers and establishes their relation with vital socio-ecological factors that limit the adoption and continued implementation of SLM practices (Figure 4.20). The study utilizes the "local actor's model" as an explanatory framework to understand how interlinkages among various drivers influence land users' decision-making in managing IAS management.

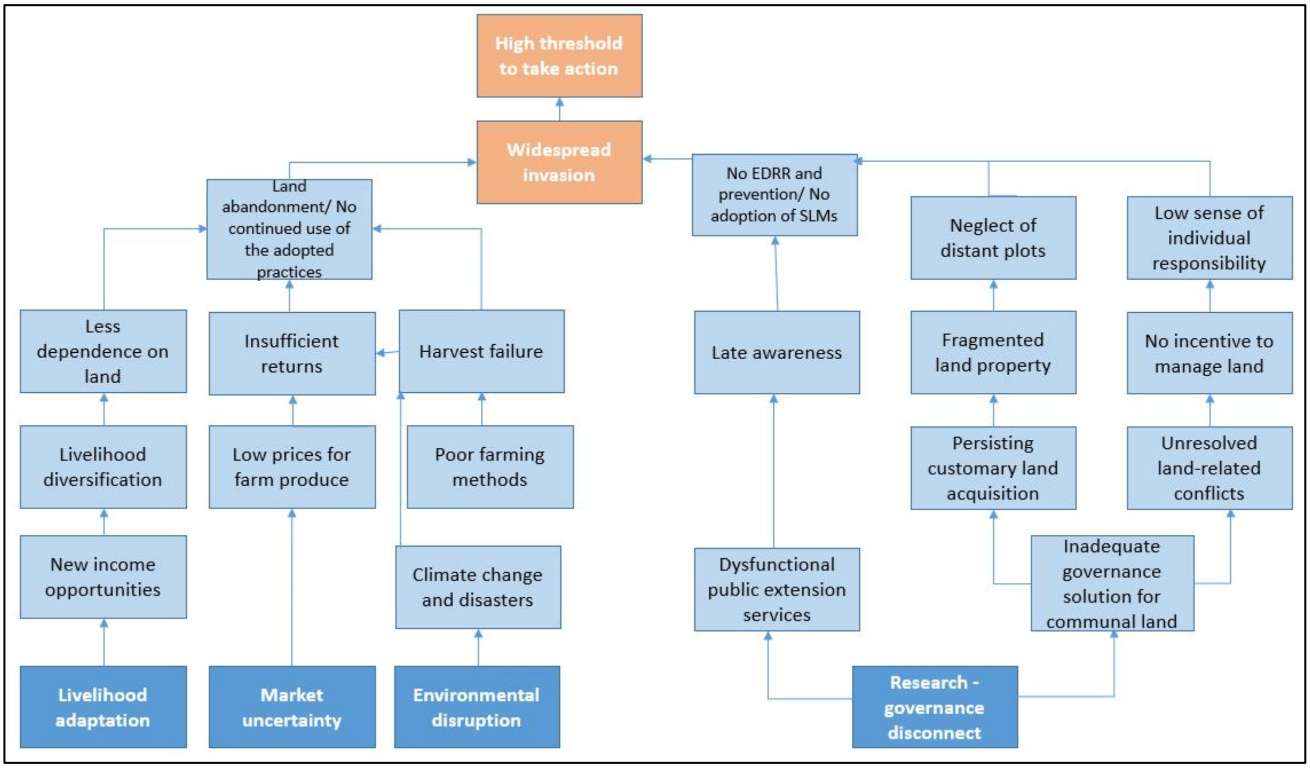


Figure 4. 19: The relationship between socio-ecological factors and the drivers that influence the adoption and abandonment of Sustainable Land Management (SLM) practices.

4.3.4.1. Critical socio-ecological factors

The four main factors contributing to the abandonment or non-adoption of SLM practices are market uncertainties, livelihood adaptation, the disconnect between land governance and research, and environmental disruptions. These factors are significant in informing invasion management strategies and failure to address them effectively may limit SLM implementation, thus hindering the successful management of invasive species. Below is a description of each of the factors in relation to their causal drivers.

Environmental Disruptions Environmental disruptions, such as natural disasters, droughts, and floods, are on the rise due to global climate change, leading to reduced productivity and crop failures (Manzoor *et al.*, 2021) . The costs associated with implementing SLM practices outweigh the low returns from these affected areas (Cowie *et al.*, 2018), resulting in land users abandoning these parcels. As a result, the initially managed parcels become more susceptible to invasion or re-invasion.

Land users perceive environmental shocks to have a negative impact on the outcomes of SLM implementation based on their experiences. Such perceived impacts of external drivers on expected returns inform land users' management decisions as illustrated in the human actor's model (Wiesmann *et al.*, 2011) . In this case, land users' perceptions limit land management practices and invasion management implementation.

Market Uncertainty: Within the irrigation schemes, where the contractual farming approach dominates, land users sell their agricultural produce to contracting companies such as the NIB. It was reported that such contractual agreements leave farmers at the mercy of contracting companies who dictate prices and sometimes purchase below the prevailing market prices. Coupled with a seasonal decrease in demand for farm products and its effect on prices, this disincentivizes SLM implementation.

As explained in the actors' model, economic drivers are among the dynamic external factors that determine land users' rationale for assigning their resources or stock of means to alternative activities (Wiesmann *et al.*, 2011). Consequently, due to the perception that market dynamics diminish their profits, land users often respond by reallocating their available resources towards alternative and more profitable economic activities (Mena, 2018).

Livelihood Adaptation: Contrary to the original intent of introducing these *P. juliflora*, which included providing fodder for livestock and rehabilitating degraded land, among other objectives (Mwangi & Swallow, 2005), *P. juliflora* has encroached on herbaceous biomass including fodder leading to a decline in livestock numbers (Ndhlovu *et al.*, 2011) . As a result of the significant expenses associated with invasive species management and the detrimental effects of environmental disruptions like droughts and floods, land users progressively shift towards alternative livelihood sources, including employment, trade, and charcoal production.

The motivation of land users to manage land from invasion declines (Cowie *et al.*, 2018), exposing the affected parcels to (re-) invasion. This illustrates that land users will most likely adapt their activities to prevailing external conditions that their actions are exposed to, such as environmental disturbances (Trang & HuuLo, 2021; Wiesmann *et al.*, 2011). According to (EW Linders *et al.* 2020), the income obtained from charcoal production as an alternative livelihood source may not match or replace the cultural value bestowed upon traditional pastoralism practice. This implies that the driving factor for livelihood diversification among community members may be attributed to the degradation of pastures within their initial grazing fields. The restoration of grazing lands may therefore present a possibility of motivating land users' engagement in communal land management.

Research and Land Governance Disconnect: Without an effective interface between science and policy, evidence-based knowledge from science only slowly or is not taken up to inform land governance decisions. This limits land management, resulting in ineffective land governance practices and dysfunctional extension services within the communal tenure system. Reliance on extension services that are not informed and guided by credible research findings often mislead land users' actions. Similarly, delayed extension services restrict timely response actions (Mena, 2018) , which enhances the progression of IAS to advanced levels for whose management becomes impossible (Bagavathiannan *et al.*, 2019b).

The customary land governance systems were considered to be ineffective in addressing the prevailing challenges related to land tenure. Its land acquisition process was perceived to contribute to land fragmentation, often associated with technical inefficiencies within croplands (Danquah *et al.*, 2019) . Further, existing land governance institutions were perceived to be weak and enhanced the occurrence of unresolved land disputes. This, in turn, disincentivized community members to engage in land management. As the human actors' model explains, local actors' perceptions and practices are firmly embedded within their social and cultural institutions. Therefore, these institutional frameworks should be reinforced to support sustainable environmental management (Wiesmann *et al.*, 2011).

Based on the above four socio-ecological factors, I compare my findings with a South African study, (Shackleton *et al.*, 2016b), which stands out as one of the rare investigations that directly tackle the obstacles hindering the management of *P.*

juliflora. Both studies concluded that land users' decisions are informed by multi-dimensional drivers; economic, political, social, and environmental, the most dominant driver being in the social category. A major difference is that the findings of this work are contextualized on specific invasion trajectories of *P. juliflora* cover. Therefore, this research advances the South African study by providing context-based drivers for managing IAS by land users. Further, in addition to the knowledge and institutional gaps highlighted by (Shackleton *et al.*, 2016b), this work identifies additional barriers to invasion management; environmental disruptions, land governance, science policy gap, and livelihood adaptations.

In contrast to (Shackleton *et al.*, 2016a) 's study, respondents in this study did not mention challenges related to technological know-how in implementing alternative IAS management options such as chemical and biological control. This shows the difference in respondents' perceptions between geographical regions. The difference in responses implies that respondents in South Africa better understood different IAS management options compared to those in the Kenyan study area. To achieve sustainable management of invasive alien species, it is crucial to integrate a combination of practices (Kropf *et al.*, 2020). However, land users' decision-making regarding the adoption of multiple approaches to control invasions is influenced by their familiarity and understanding of various alternative practices (Gill *et al.*, 2018). his means that land users are more likely to adopt practices that they are knowledgeable about and have proven to be effective. It is worth noting that, up to this point, there have been no attempts to manage *P. juliflora* through biological or chemical methods specifically in Baringo County or within Kenya as a whole. This is despite the emphasis on the benefits of biological control, which is a 'natural' management approach that is self-sustaining once released to the invaded zone. (Bagavathiannan et al., 2019; Zimmermann & Maennling, 2007) . Therefore, land users should bench-mark from implementers of suitable alternative management approaches to widen their knowledge and promote initiatives in their implementation.

Both studies also reported conflicting interests due to benefits derived from *P. juliflora* leading to land users' reluctance to control their spread. However, in this study, the challenge primarily pertained to sparsely invaded areas where respondents had limited hands-on experience with the significant expenses associated with clearing advanced invasions (Kropf *et al.*, 2020).

4.3.5. The potential entry points for achieving sustainable IAS management

The results of this study validate that the sustainable management of invasive alien species (IAS), such as *P. juliflora*, cannot be effectively accomplished at the individual plot level. The study underscores the importance of collaborative and coordinated initiatives that involve all relevant stakeholders across privately and communally owned land parcels at a landscape scale (Bagavathiannan *et al.*, 2019b; Kropf *et al.*, 2020). However, certain barriers hinder the effective implementation of such coordinated efforts. Addressing challenges to land users' uptake and continued use of SLM practices will therefore allow for better performance of the enabling drivers leading to higher adoption and implementation of SLM practices for sustainable management of IAS. The next chapters, therefore, detail some potential entry points toward a successful IAS management strategy, such as Kenya's National *Prosopis* Management Strategy.

4.3.5.1.Strengthening community resilience in the context of environmental disruptions

Based on the findings of this study, the most effective approach to addressing any environmental disturbance is to convince land users that their efforts to manage the land will not be in vain. Therefore, it is crucial to enhance community members' resilience to environmental disruptions, which often have adverse impacts that exceed the local community's local capacity to respond adequately. However, building local capacity and strengthening community resilience should extend beyond relying solely on external support. Instead, actors should explore alternatives to adapt land users' activities, reducing uncertainty and adapting to the dynamic conditions in which they operate. The latter is more likely to yield better outcomes (Wiesmann *et al.*, 2011).

A key aspect of early preparedness is the external support from local, national, and international institutions in constructing infrastructure that enhances community resilience to natural disasters. However, modifying conditions within which land users operate is likely to yield better results than mere reliance on external aid. For instance, since collective action enhances the chances of attaining a resilient community (Niemiec *et al.*, 2020) , building robust social networks at the grassroots level has the potential to enhance the ability of community members to effectively organize themselves, gain valuable insights from past environmental disturbances, and implement adaptive measures to recover and withstand shocks. (Jacobi *et al.*, 2019).

Despite the construction of infrastructure, some impacts of extreme weather events such as floods and drought are inevitable. To respond to such cases, especially in farmlands where natural disasters may result in huge losses, programs to compensate farmers against losses through robust insurance schemes may be necessary. The purpose of this initiative is to increase resilience against environmental shocks, and to encourage land users to remain actively involved in the implementation of Sustainable Land Management (SLM) practices. (Banadda, 2010; Jacobi *et al.*, 2019) . Further, to avoid such losses, land users should adapt their conditions of operations by avoiding disaster-prone areas. This requires establishing land use plans to restrict and guide human activities within disaster-prone zones, especially along rivers and other flood-prone areas- often preferred for farming owing to their constant availability of water. However, enforcing such plans requires strong institutions within socially defined norms (Kropf *et al.*, 2020). Thus, strengthening community-based institutions is essential in enforcing such land-use plans and ensuring community members comply.

4.3.5.2. Regulating market actors and the control of prices

The findings of this study illustrate that land users will rarely implement SLM practices if they do not expect to benefit from them. This can be attained if a fair environment that guarantees sufficient returns to smallholders through price and market regulations is created to minimize their risk of exploitation. Therefore, contracting institutions may protect land users from monopolization by formulating and enforcing policies that regulate market prices and promote equitable market access (Danquah *et al.*, 2019).

To this end, it would be imperative to coordinate land users through cooperatives that advocate for improved farmers' rights in setting prices and regulation of market access. This might enhance the confidence of land users in benefiting from their management efforts and hence continue with SLM implementations.

4.3.5.3. Combining poverty alleviation and environmental management

Integrating poverty alleviation into environmental management is a widely promoted initiative toward achieving sustainability (Zhang & Putzel, 2016) . This is because community are inclined to update and modernize their livelihood systems by embracing new and appealing income opportunities. To effectively tap into this potential, it is crucial to prioritize and support livelihood activities that directly rely on Sustainable Land Management (SLM) implementation., such as farming. Such practices should be prioritized as primary rather than supplementary income sources as defined in the Baringo County Development Plan (County Government of Baringo, 2018) . However, it should be noted that promoting such land-dependent economic activities requires resources such as land, labor, and water. As a result, it is recommended to establish flexible land markets that promote land redistribution to individuals who can easily convert the land to meaningful uses and limit invasion.

While land subdivisions may be important for managing individual parcels of land in the context of the growing population, they can have a negative impact on the management of invasive alien species (IAS) at a landscape level. Such implications were experienced in California, where landowners focused on managing the invasive *yellow starthistle* just within their parcels while neighboring parcels whose owners failed to manage the invasive species acted as a source of invader propagules to managed lands (Epanchin-Niell *et al.*, 2010) . A key lesson learned illustrates that the management of communally shared lands like grazing lands requires a collective action that incorporates all land users. Indeed, it was revealed that land users often adopt practices in solidarity with their communal, collaborative efforts (Kropf *et al.*, 2020), provided a social relationship and trust exist among the concerned parties (Gill *et al.*, 2018). As such, a promising solution may be to replant communally shared parcels with native grasses and trees whose management is delegated to some assigned community members.

The engagement of community members may be secured if their efforts are compensated through village development programs like establishing infrastructure and enforcing as well as securing land use rights. In this context, environmental management is intertwined with social and economic progress, resulting in reduced poverty within the affected communities. To encourage widespread participation, the implementation of social sanctions against uncooperative individuals has proven to be effective in fostering cooperation among community members (Kropf *et al.*, 2020).

The presence of several factors contributed to the positive perception and utilization of Prosopis, rather than its spread being managed. These factors included the simultaneous occurrence of a market opportunity for charcoal, policy provisions that made charcoal trade licensing easier, and the tendency to diversify livelihoods beyond farming. To effectively manage Prosopis, it is crucial to harmonize these diverse policy instruments. This finding aligns with the idea that successful outcomes should integrate actors' activities, the means used to achieve those activities, and the interpretations of the outcomes (Wiesmann *et al.*, 2011). Thus, improving access to land (means), and its associated potential to alleviate poverty (meaning of actions) through appropriate ad resilient farming practices (actors' activity), provides a comprehensive entry point in achieving sustainability in land management.

4.3.5.4. Engaging the community and raising awareness

Based on the findings of this study, scientific evidence is fundamental in informing land governance on IAS management since it reveals drivers to land users' management decisions, as well as hotspot areas to be prioritized for management. For instance, this study identified communally owned land and irrigation schemes as vulnerable to invasion hence a recommendation for innovative management strategies to be employed on such parcels.

Even though efforts have been made to research invasion management, innovative extension services are needed to trigger communal actions at the landscape scale. Similarly, introducing demonstration plots, attractive community field days, and dedicated programs to appreciate SLM champions might motivate participation in SLM implementation and provide interactive platforms for disseminating and disseminating research innovations (Jakhar & Rai, 2020). A study in Mongolia found that integrating diverse information sources promotes knowledge exchange and rangeland management (Ulambayar & Fernández-Giménez, 2019).

4.3.5.5. Efficient approaches to land governance

Apart from creating awareness, enforcing tenure rights may contribute to land governance solutions which are key for SLM implementation. According to (Van Song *et al.*, 2020) , the adoption of a consolidated land ownership approach holds the potential to enhance access to land and streamline land management. One way to achieve this is through the establishment of flexible land markets that encourage transactions for parcels that are neglected and at risk of abandonment. However, it's important to note that this approach applies only to individual parcels governed by customary occupancy rights, as specified in the Kenyan Community Land Act of 2016. On the other hand, the management of communally shared parcels, which are frequently neglected and susceptible to disputes, poses a more intricate challenge (Tebboth *et al.*, 2020).

The subdivisions of land, as encouraged by land markets, despite being instrumental in controlling invasion on individual parcels, are considered a hindrance to IAS management, especially at the landscape level. Land users often neglect the management of collectively owned parcels because they lack incentives to do so

(Epanchin-Niell *et al.*, 2010) . Overcoming the challenge of joint registration for communally shared parcels could lead to positive results. This approach is likely to encourage the legitimate members of the community to collectively utilize and manage shared resources (Wily, 2018) . This is because legitimate beneficiaries are recognized and held accountable for managing such resources. A practical example of a successful collective and participatory action in controlling IAS is the participatory enforcement of regulations guiding the utilization and management of the Tanzanian Simanjiro (Adoyo *et al.*, 2021) . The study in Tanzania consider the benefits shared by community members as a great incentive that encourages members to manage invasive species. This indicates that in order to ensure the effective management of communally shared lands, a coordinated approach should be adopted, along with shared benefits for land users (Bagavathiannan *et al.*, 201; Epanchin-Niell *et al.*, 2010).

Implementing the interventions mentioned above collectively by community members, who play a crucial role as agents of change, can greatly improve invasion management. However, this necessitates the presence of an effective institutional framework that facilitates the timely resolution of land-related disputes. Community-based tenure rights enforcement procedures that enhance community enforcement officers' legitimacy should be established to achieve this.

4.4. Tenure right barriers that influence land users' implementation of SLM practices to manage the invasion of *P. juliflora*

This section presents the findings of the fourth objective on the prevailing tenure regimes and how tenure rights hinder or enable the implementation of SLM practices. It also evaluates the effects of livelihood changes on SLM implementation and how responsive the prevailing tenure rights are to such changes.

4.4.1. Historical alignment of cultural practices with customary tenure rights enforcement

Customary tenure is the dominant form of tenure in Marigat Sub-County. The study findings show that 80% of the land parcels were acquired through the customary land acquisition process and have had title deeds, while the rest (20%) were either leased or purchased. Interviews with area chiefs clarified that the parcels of land in the area majorly fall within the customary tenure system, with community members being assigned individual rights of occupancy, usage, and management.

Land ownership is mainly male dominated, while women are assigned secondary rights of usage through their spouses (Personal interviews with local chiefs, October 2019). Following the provisions of the customary tenure system, access to tenure rights is restricted to legitimate community members. This provision locks out married women with whom their communal belonging is considered illegitimate, especially when they marry. Such positions render women vulnerable in accessing land to implement SLM practices.

The findings from this study established that some customary practices, beliefs, and regulations in the past enhanced the effectiveness of community engagement in environmental conservation. This was attributed to the fact that the functionality and security of the customary tenure system were firmly embedded in cultural beliefs and practices-which defined individual behaviors. However, the land management practices and strategies that were enforced targeted communal lands such as pastureland. Thus, seasonal and rotational grazing was widely practiced and coordinated by the clan elders who restricted and demarcated season grazing lands, specifically during the dry seasons. No permission was granted for cultivation or settlement within grazing areas. According to the interviews, the dry season grazing land was officially opened up through sacred ceremonies performed by traditional leaders or elders. Based on responses from the chiefs, community members strictly adhered to these customary rules for fear of being cursed or penalized. For example, livestock found in seasonally prohibited zones were painted with a familiar mark to indicate non-compliance forcing the owners to offer a cow as a fine or penalty. A committee of elders was elected to enforce the management of communally shared lands while the young men monitored cases of non-compliance (Personal interviews with area chiefs, October 2019).

While the previously mentioned measures effectively addressed land-related resources among pastoralists, the shifting livelihood patterns have altered the management priorities of land users. The increasing modernization and the emergence of alternative non-pastoral livelihoods, such as formal employment, trade, sedentarization accompanied by agropastoral activities like cultivation (Figure 4.21), higher levels of formal education, growing literacy in the region, and religious influences, have likely impacted communities' association with traditional beliefs.

For instance, the belief in potential curses for disobeying directives from clan elders may have been affected. As a result, the customary institutions responsible for enforcing tenure rights have weakened, leading to the neglect of communal land management and the subsequent encroachment of *P. juliflora.*

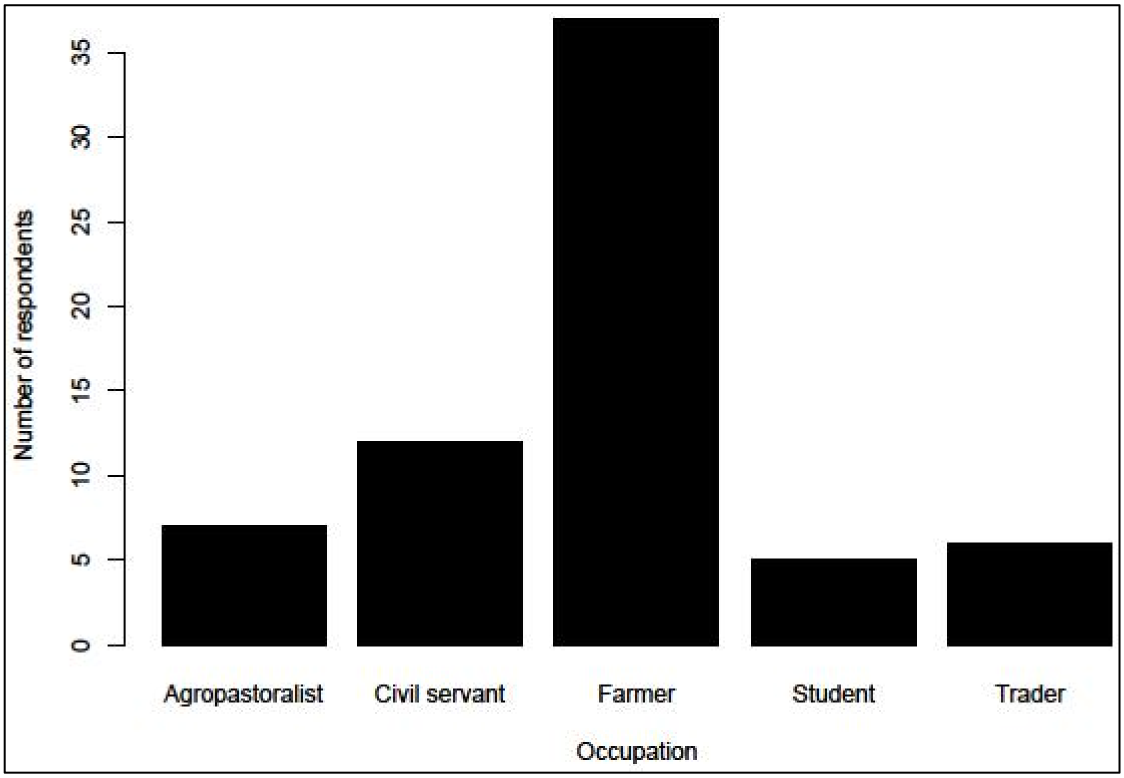


Figure 4. 20: Main occupation of respondents in the study area

Narratives from respondents and chiefs indicated that being majorly pastoralists, male members of the community were permitted to migrate and settle on any unoccupied piece of land. As long as they were the first occupants, it became theirs rightfully despite subsequent relocations. Consequently, the aged people possess more parcels beyond their capability to implement SLM practices against invasion. An analysis of responses collected through questionnaires established that the number of parcels of land and the total size of land owned increases with age (Figure 4.22). Coupled with the limited resources, most aged landowners cannot effectively manage invasion on their numerous and fragmented parcels.

The findings show that most youths below the age of 20 years have only one parcel of land occurring within a narrower range of between 1 and 3 acres, while the older adults above 59 years old have the largest parcels, an average of 8 acres of land. However, the broadest range in size of land owned occurs among the middle age group (40 to 59 years old), who have between 1 to 2 parcels of land ranging between 2.5 to 7 acres. The concentration of land among older people is ascribed to the provisions of the customary land acquisition process and the belief that customarily acquired land is not supposed to be sold but can only be inherited in the community lineage. On the contrary, due to the growing population that depends on fixed resources, the current generations were reported to be engaging in selling and purchasing land since this might be the only means for acquiring land in the area.

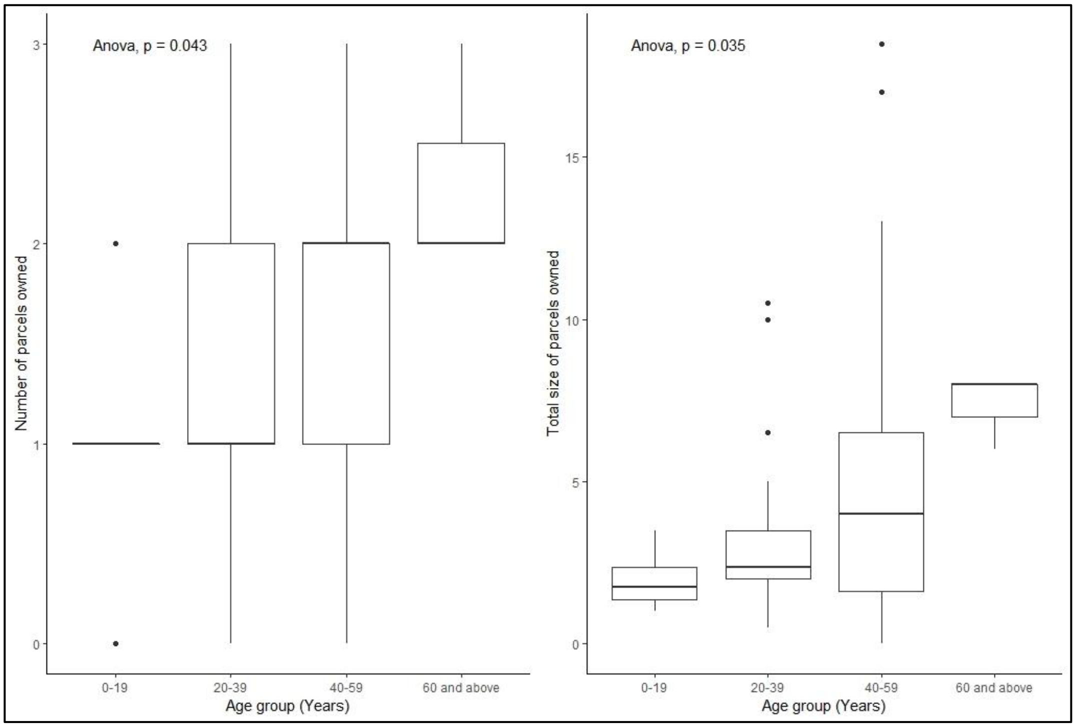


Figure 4. 21: The number and size of land owned segregated by age group.

4.4.2. Customary tenure verses privatization of land on invasion management

Respondents perceived that the customary tenure system is not responsive to livelihood diversification, making ancestral land prone to privatization. At the time of the study, communal lands were subdivided, and titles were often issued. Data from the lands' office confirmed that more than 1553 titles were issued in 2019 in Marigat Sub-County, and more land is in the process of privatization. Local politicians allegedly supported the privatization process without considering its implications on the communally shared resources such as grazing lands (Personal interviews with the County lands officer; October 2019). Alternative sources of income were perceived to have enhanced the need to privatize land, as most respondents (81%) perceive that they would benefit more from privatized land compared to communal land (Figure 4.4.4). Thus, the majority of respondents (91%)

are willing to implement invasion management practices on their private farms rather than on communal land.

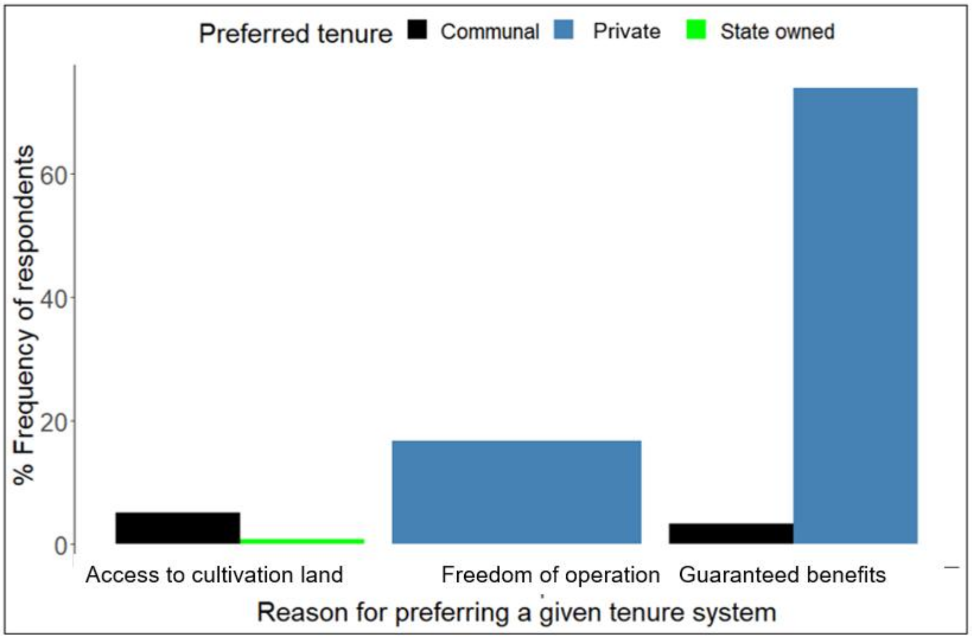


Figure 4. 22: Motivation for tenure system preference.

The preference for investing in private lands instead of communal lands indicates that the customary tenure system is perceived as inadequate in guaranteeing the rights and benefits of its tenure holders. Consequently, this perception hinders the implementation of invasion management practices (Figure 4.22).

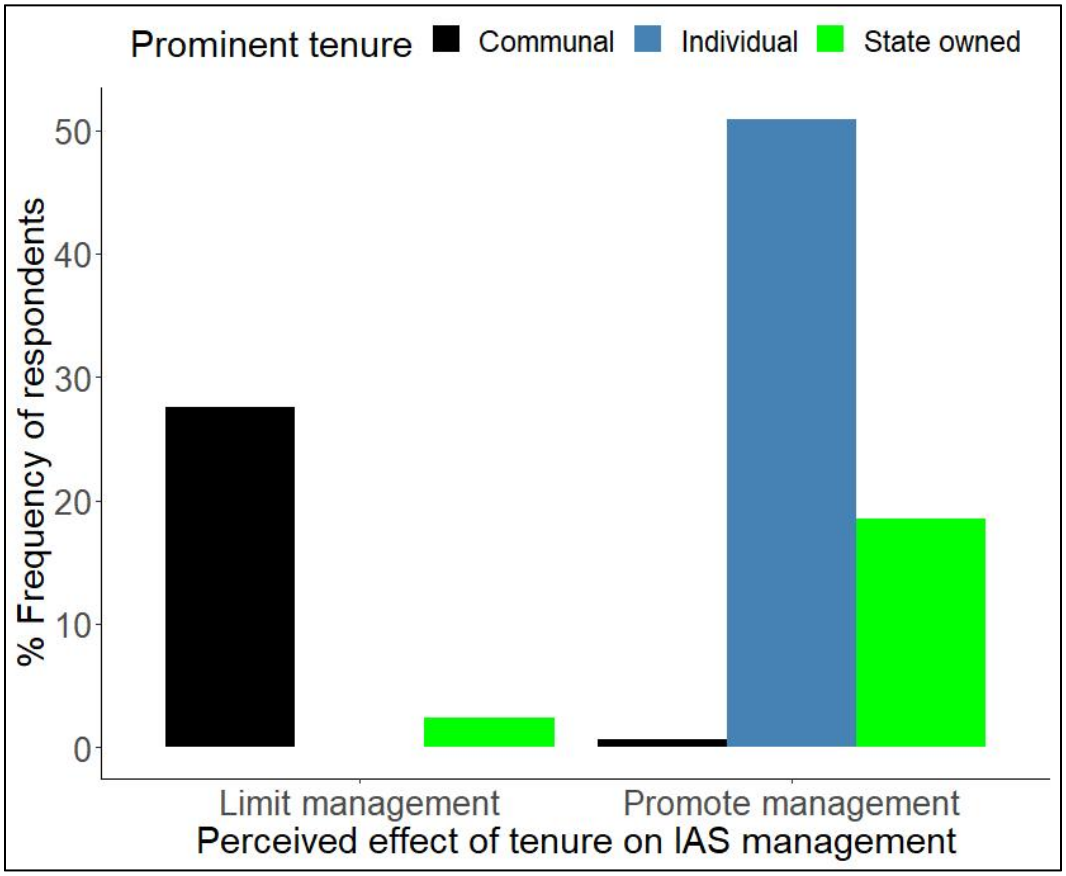


Figure 4. 23: Contribution of different tenure regimes to the management of *P. juliflora.*

The perceived insecurity of communal tenure systems explains the resistance exhibited by communities towards engaging in management initiatives such as conservancies. Community members view these interventions as schemes to transfer communal land to investors, with limited direct benefits reaching the community. These perceptions demonstrate that land users are more likely to engage in land management activities when they believe they will benefit from their involvement. This is evident in the fact that the majority (41%) of land use changes in the study area are driven by the need to generate income through activities like agriculture, plantation forests, or pasture cultivation. Consequently, irrigated parcels, which offer economic benefits, have been predominantly maintained under irrigation (61%). Furthermore, over 50% of the parcels cleared of *P. juliflora* were utilized for irrigation-based cultivation. Similarly, the establishment of pasture plantations, which generate income through the sale of harvested grasses, is widely practiced. Among the parcels currently under planted pastures, 67% were initially invaded by *P. juliflora* (Figure 4.24).

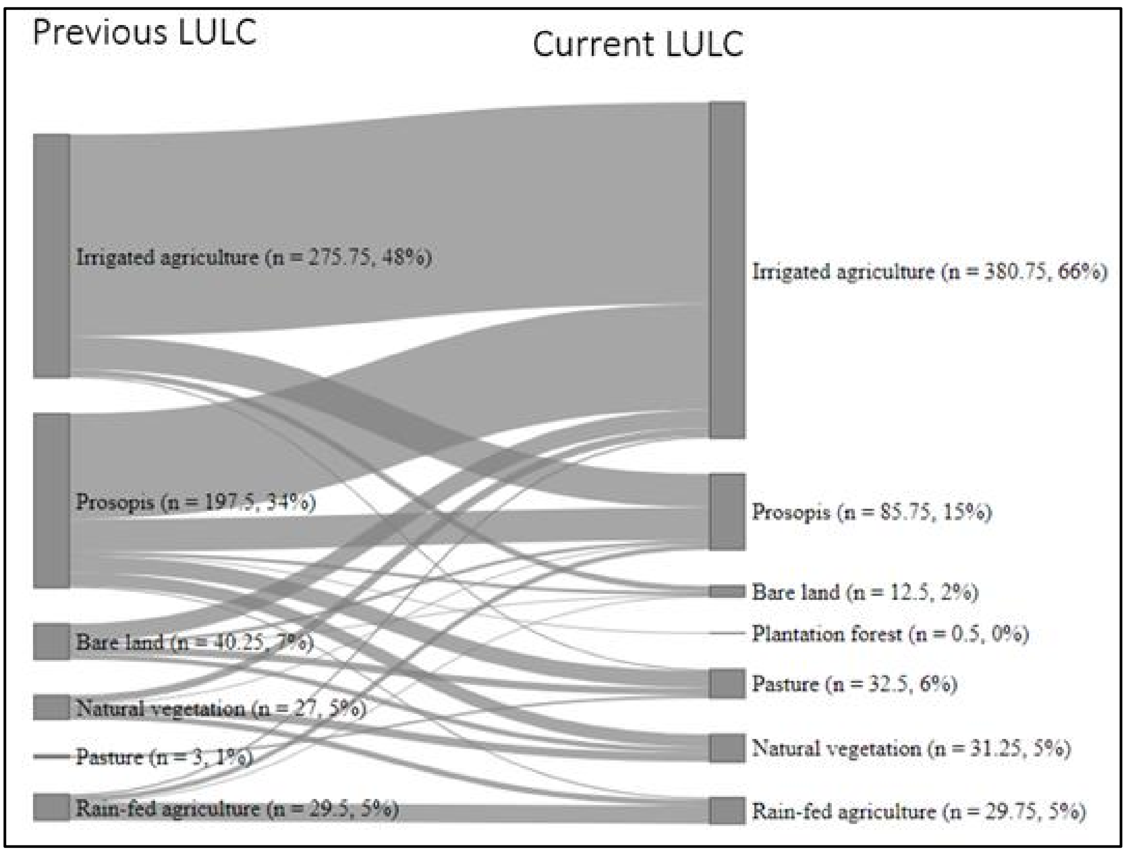


Figure 4. 24: Changes in land uses by respondents

While the findings presented above imply that private lands are preferred for the implementation of SLM practices, it is worth noting that in pastoralists' dominant areas, such as Ruko conservancy, which is under a communal tenure system, community members are resisting sub-division to enable free movement of livestock (Personal Interviews with area chiefs; October 2019). This indicates that privatization may not be suitable for all forms of livelihoods in the area but vary with the livelihood system and locality. Pastoralists' dominated areas preferred communal tenure where land is entirely owned and used in common by all community members as this is perceived to support the free movement of livestock.

4.4.3. Customary tenure enforcement institutions

Tenure rights in the study area are majorly enforced by the local authorities (82%), such as the chiefs and council of elders. Local authorities are responsible for resolving land-related disputes and enforcing community land management rules. Most respondents (69 %) perceive tenure-right enforcers to face challenges in performing their roles effectively.

First, the lack of land demarcation makes it challenging to identify legitimate land boundaries leading chiefs and the council of elders to rely on temporary land boundaries and witnesses, which are unreliable in ascertaining the limits of tenure rights. Secondly, there is a threat of corruption and land grabbing by influential members of society, limiting the chances of fair judgment in cases of land-related disputes. Such unfair treatments denies vulnerable community members, such as women and people with low incomes, access to their legitimate land rights. Likewise, it is perceived that communal "respect" for the chiefs and council of elders has declined with time. Thus, their counsel and advice are often ignored by community members.

"C*ommunity members prefer settling their disputes in formal judicial institutions like courts, which they consider more legitimate, and whose judgment cannot be challenged unless through an appeal process. Likewise, they seem to have lost confidence in the chiefs as they perceive that chiefs are corrupt and often favor their relatives*" (one of the chiefs in the study area).

The third hindrance to land tenure rights enforcement was that most local tenure rights enforcers have limited knowledge of the modern institutions, legislation, and policies that govern land tenure and may not recognize them or support their enforcement. Finally, most land rights enforcers lack the motivation and requisite capacity - financial resources and relevant training - to carry out their mandate.

The study observed that land allocation through the customary tenure system does not involve a clear demarcation of land boundaries. Temporary boundaries and community witnesses have long been used in resolving conflicts related to land disputes. However, with an increasing demand for land and the demise or absence of witnesses, customary land is faced with disputes over unclear boundaries (Personal interviews with area chiefs, October 2019). In all cases, the disputed parcels are often left unattended during the dispute resolution process, thereby exposing such parcels to invasion by *P. juliflora.*

4.4.4. Tenure right barriers to the implementation of IAS

The findings of this study established that implementation of SLMs on private and communal lands is hindered by tenure right barriers, which vary depending on the nature of the tenure system and the use to which land is assigned. This chapter, therefore, looks at the barriers in the context of existing literature and proposes possible intervention measures to mitigate their implications on managing invasive species.

4.4.4.1. Challenges associated with the customary tenure system

The customary tenure system, the most dominant tenure system in the study area, contributes to the governance of land transactions in East Africa's rural areas (Arko-Adjei, 2011; Greiner, 2016) . However, due to the patriarchal system, customary tenure restricts women's direct access to land through their spouses, despite their significant role in utilizing and implementing different land management practices. This may limit women's full participation in implementing SLM practices (Kasimbazi, 2017). Likewise, the land acquisition process under the customary tenure system has resulted in the disproportionate distribution of land in a manner that hinders effective land management. While the aged members of the community have limited resources and capacity to engage in invasion management, the traditional land acquisition process has resulted in them owning vast parcels of land, most of which is exposed to invasion. According to (Danquah *et al.*, 2019) , customary land acquisition contributes to land fragmentation, enhancing technical inefficiencies in implementing SLM practices. This is more common, especially on croplands, as farmers would prefer to channel their limited resources into cultivating parcels close to their homesteads, making distant parcels vulnerable to invasion. This finding is similar to that of (Murken & Gornott, 2022), who confirmed that provisions of customary tenure systems promote the vulnerabilities of some socio-demographic groups, such as women and migrants. Optimizing equity in the access to tenure rights should therefore be enforced to incentivize land users' adoption of SLM practices.

The customary tenure system also presents limitations on land markets that encourage the disposal of land which the owner cannot adequately utilize (Odhiambo, 2016). This position is similar to our findings that the customary land acquisition process has resulted in many older people owning large parcels, which they cannot successfully implement SLM practices. Such parcels have thus been invaded as the owners believe that customary land should not be sold, yet they cannot effectively manage them. However, the young generation, who are faced with unemployment, were reported to have defied these directives and are currently informally selling or purchasing land, a position that agrees with (Greiner, 2017), who states that the customary tenure system does not prevent commodification and trading in ancestral land. The small number and sizes of land owned by young respondents were perceived to contribute to effective land management as landowners are committed to the few parcels they own and thus try their best not to lose them to invasion.

4.5.5.2. Community perceptions of the tenure right barriers

This study has established that land users prefer different tenure systems based on the implications of the tenure provisions in improving their livelihoods and well-being. As such, the surety of anticipated benefits derived from managing land is vital in encouraging land users to engage in land management practices

(Bagavathiannan *et al.*, 2019a; Epanchin-Niell *et al.*, 2010). The perception that the customary tenure system presents insecurities in accessing tenure rights limits land management efforts on such parcels. It should, however, be noted that benefits derived from different tenure systems vary with the livelihood system. This is seen in farmers' and pastoralists' diverging preferences for different tenure systems. While farmers anticipate deriving benefits from the freehold tenure system, the pastoralists would prioritize managing communally owned pasturelands, which would better facilitate their zero-grazing practices. This conflict of interest illustrates the importance of an integrated tenure system that fits a community's mosaic nature of livelihood systems.

4.4.4.2. Livelihood transitions

Pastoralists' way of living is rapidly changing as a response mechanism to environmental disturbances and the desire to improve their livelihoods through market-oriented and relatively successful pathways (Kirui *et al.*, 2022) . The implications of such transitions are observed in the abandonment of customary beliefs and practices. This was reported to result in a loss of confidence and respect for traditional leaders who enforce tenure rights. The abandonment of traditional land management practices, coupled with the declining respect of traditional leaders, has thus weakened collective land management strategies, which are vital in managing the complex invasion process (Epanchin-Niell *et al.*, 2010).

Traditional leaders' structural manner of managing and enforcing customary tenure rights seems to have degenerated with livelihood systems. The practices that ensured sustainable management of communally shared resources such as pasturelands are currently neglected as community members venture into other income-generating activities like farming, trade, and formal employment. Consequently, they do not prioritize the management of land parcels that do not directly support their current livelihoods (Nkomoki *et al.*, 2018).

The above findings agree with a study in Pokot, which found that as communities adopt sedentary lifestyles with livelihood changes from pastoralism to farming, their claim to individual ownership of land increases to enable them to manage their farmlands efficiently (Greiner, 2017). The question, however, is how to address livelihood transitions in such a way that the rights and livelihoods of the remaining pastoralists are secured. Adopting flexible land management practices that allow for livelihood transitions while maintaining the efficient management of communally shared parcels is, therefore, imperative.

Likewise, the reliance on cultural and traditional practices to ensure compliance with land management laws continues to face limitations given the changing religious alignment to modern Christianity, leading to the disregard of customary land administrators whose judgments are guided by the cultural and customary provisions. The resultant ineffective land administration leads to land-related injustices and unresolved conflicts that limit sustainable management (Kasimbazi, 2017), including the fight against invasion by *P. juliflora.*

4.5.5.6. Limitations of Community Land Act (2016) in addressing communal tenure right barriers.

The challenges of tenure systems were anticipated, and an attempt to address them was detailed in land-related legal documents such as the Kenyan Communal Land Act (2016). In anticipation of prevailing livelihood transitions, the act provides for community land - vested in the community - to be held under customary, freehold, or leasehold tenure systems. It also provides for registered communal land to be reserved for different purposes: grazing, settlement, and farming, as may be approved by the community assembly. Unlike the provisions of the Act, community lands in the study area have not been registered to enhance tenure security through the issuance of a legal, communal title deed. Instead, politicians have encouraged the allocation of individual title deeds which are deemed illegal according to the provisions of the law. According to the Community Land Act 2016, conversion of registered community land to private land is permitted through transfer or allocation by the community assembly, upon which an allotment letter (customary right of use and occupancy) is issued instead of a separate title deed. This was meant to ensure that individual landowners remain answerable to the community on matters related to the use and management of land. Based on (Wily, 2018), formalization through titles is less effective in communal land management as compared to the well-established customary system, on the condition that customary tenure rules are effectively enforced.

While the observed illegalities might be related to inadequate knowledge of existing regulations by local land enforcers, politics and powers play a great role in land governance and, thus, decision-making. In essence, land governance is defined by power and political economy factors associated with land (Palmer *et al.*, 2009; Sales *et al.*, 2016). The role of politics in formulating policies to suit their intended needs may render such policies non-responsive and ineffective in addressing practical and contextualized challenges faced by local land users. The above discussions imply that the main challenge to implementing SLMs lies in enforcing regulations that guide the management of customary land (Arko-Adjei, 2011; Greiner, 2017; Wily, 2012). However, target areas for management and measures to ensure compliance have proved incompatible with prevailing livelihoods. For instance, practices that specialize in managing pasturelands may not apply to the management of individual farmlands.

According to (Greiner (2017) and Wily (2012), unclear boundaries are a challenge to the customary tenure system, which has led to communal land grabbing and unresolved disputes. In most unresolved cases, it is perceived that a lack of reliable witnesses has rendered such conflicts unresolved for a long time, making it impossible to manage such lands due to pending disputes. Grainer (2016) posits that customary land laws are not legally binding, and conflicts can only be resolved if both parties reach a consensus, and this makes it difficult to resolve disputes under the customary tenure system. The formalization of the roles of local tenure right enforcers, such as chiefs in the Community Land Act of 2016, may thus enhance their capacity and contribute to more effective enforcement of tenure right barriers.

CHAPTER FIVE: SUMMARY OF KEY FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1. Introduction

This chapter provides a summary extracted from the research, outlining key conclusions drawn from the study's findings. Additionally, it offers recommendations to various stakeholders to facilitate the sustainable management of invasive species.

5.2. Summary of key findings

The findings of this study illustrate that awareness creation and sensitization are critical in shaping land users' perceptions and prioritizations of invasion management and that participatory processes are important in defining land users' actions toward the desired management trajectory. However, prospects for direct economic benefits are a key determinant as to whether or not the affected land users will engage in the actual implementation of SLM practices. An effective *P. juliflora* management strategy should therefore incorporate direct economic incentives for land users to be adopted and supported for sustainable implementation at the local level.

Land users' management decisions are shaped by the knowledge they gain during awareness creation and sensitization processes influencing their perceptions, beliefs, and motivations to engage in land management actions. The preferences for particular SLM practices were attributed to how land users perceive the SLMs in terms of their effectiveness in achieving the intended management goals, the compatibility of SLM implementation with local cultural norms, as well as the limitation of land users' knowledge of the anticipated outcomes of implementing such practices. For instance, land users had limited knowledge of the impacts of chemical treatment on invasive species management, making them least desirable among land users. More generally, despite their effectiveness in managing invasion, land users tend to take precautionary measures against implementing SLM practices with unknown potential impacts. Therefore, awareness creation through practical benchmarking programs is necessary for community members to feel comfortable implementing the less popular practices within their locality. Similarly, prohibitive practices-those that restrict land users from deriving benefits - are less likely to be implemented unless integrated with other desirable and less prohibitive practices. Thus, this research concludes that land users are more likely to desire a combined set of management practices than a single practice. Probably, land users perceive integration of multiple practices as the best way to maximize opportunities to manage invasion while at the same time enhancing economic benefits derived from them. This is a crucial lesson to promote integrating multiple compatible practices in managing invasive species.

The analysis of this study produced three main invasion trajectories which are related to different land management decisions: constantly invaded areas were associated with failure to adopt and implement SLM practices, constantly uninvaded areas represent the continuous implementation of SLM practices to clear *P. juliflora*. In contrast, re-invaded areas were associated with areas where SLM implementation was discontinued after initial implementation leading to re-invasion. The general trend is that constantly uninvaded areas steadily decrease with time while the constantly invaded areas significantly increase in coverage. These trends indicate that

P. juliflora management is rather the exception than a rule in the study area. The decreasing size of the constantly uninvaded areas suggests that land users are either passive or overwhelmed in the face of successive invasion occurrences. Therefore, understanding the drivers of this category is essential in informing sustainable and context-dependent management.

The constantly uninvaded areas are concentrated within agricultural lands, especially along rivers with constant water supply for irrigation and settlement areas. Re-invaded areas are close to constantly uninvaded parcels, while the constantly invaded areas dominate along roads and in some irrigation schemes. At the early stages of invasion, the key challenge to sustainable invasion management is the disconnect between research and governance. This results in inefficient extension services as illustrated by delays in information dissemination, non-supportive tenure rights systems, and weak tenure right enforcements. These three factors limit land users' capacity to adopt SLM practices, as well as their implementation of SLM practices.

While existing gaps between research and governance hinder the adoption of SLM practices at early stages, failure to continue implementing SLM practices was associated with socio-economic transformations from land-dependent livelihood systems, existing market uncertainty, and environmental disruptions, all of which point to whether SLM implementers are likely to derive net positive gains from their management efforts. Thus, practices that limit economic returns to the land user or depend on land will likely be abandoned, leading to the re-invasion. While socio-economic drivers such as tenure systems, livelihood systems, and knowledge of the impacts of invasion are the most prominent in shaping land users' decisions to implement sustainable land management practices, such drivers are interlinked to the economic, political, and environmental drivers. Therefore, sustainable land management practices may be achieved if all drivers are simultaneously considered and addressed.

The lessons learned from the findings of objective 3 (drivers to land users' management decisions) are essential in informing invasion management and thus present critical aspects that can be considered and integrated into Kenya's National *Prosopis* Strategy (NPS). The study findings emphasize the importance of continued implementation of Sustainable Land Management (SLM) practices for effective invasion management. The success and sustainability of these practices rely on active participation by the community. However, the extent of land users' involvement is determined by the benefits they receive from their management efforts. To enhance anticipated benefits and encourage greater engagement in SLM implementation, it is recommended that the National Park Service (NPS) incorporate programs aimed at building community resilience to mitigate the negative impacts of external drivers and maximize gains.

Integrating management objectives with livelihood enhancement, such as improving access to the market, can foster greater participation from land users in implementing SLM practices. It is worth noting that current invasion management efforts primarily focus on privately owned land, neglecting the vulnerability of communally shared lands to invasion. To address this, the enforcement of tenure rights is necessary to promote ownership and responsibility, thereby stimulating management efforts on communal parcels. While privatization may facilitate land redistribution and enhance SLM implementation on individual parcels, a collective approach, such as collective registration and utilization, is more suitable for managing invasion on communally shared lands. In both cases, the strengthening of communal land management institutions plays a crucial role in effective land governance and invasion management. These institutions need to be informed by credible research findings to offer viable solutions to tenure-related challenges. Therefore, invasion management strategies should be guided by land management institutions that have access to relevant research innovations.

In the study area, the customary tenure system prevails as the dominant approach, which has played a significant role in maintaining a biodiverse and healthy ecosystem over time. Despite this success, there are inherent weaknesses which, together with external pressure (e.g., land grabbing) and demographic changes, have combined to destabilize the system leading to unsustainability in land management practices. Among the most critical weakness of the customary tenure system is the patriarchal bias, which limits the capacity of women to engage in effective SLM implementation.

Owing to the above challenges, tenure right enforcement institutions have been weakened, leading to land-related injustices, and unresolved conflicts, all of which hinder the implementation of SLM practices. Furthermore, the lack of boundary demarcation, and the perception that its provisions are not legally binding, hinder tenure right enforcement.

The failure to formalize the role of local enforcement officers such as the chiefs, especially in the context of the community land act, also limits their ability to effectively engage in dispute resolutions to pave the way for continued SLM implementation on the disputed parcels. Likewise, inadequate knowledge of existing tenure reforms leaves them unequipped to make informed land management decisions. This is seen in the failure to register communal lands within the study area, as well as engagement in illegal land allocations and issuance of title deeds. Customary tenure practices that focus on managing traditional livelihood systems, such as pastoralism, are inflexible and incompatible with prevailing livelihood transformations. Therefore, the dependence on cultural beliefs to achieve compliance is no longer relevant in the current tenure right enforcement. This is because land users' judgment is shaped by modern education, which seeks logic in reasoning, and religious transformations, which tend to dismiss some of the cultural beliefs. Likewise, practices that specialize in managing pasturelands may not apply to managing individual farmlands. Also, the customary tenure system is against the commodification of land, as ancestral land can only be inherited from one's lineage. This perspective is said to have resulted in the concentration of large parcels of land among a few individuals who cannot manage them; thereby, their prioritization of a few parcels leads to the invasion of those least or not attended parcels.

5.3. Conclusions

This study concludes that the participatory involvement of land users in land management decisions increases their intrinsic value for environmental conservation.

A structured integration of community members in designing an invasion management strategy is likely to enhance their knowledge of the impacts of invasion and thus motivate them to prioritize the management of invasive species.

While a sustainable land management strategy widely builds on the three pillars of sustainability dimensions (socially acceptable, environmentally friendly, and economic viability), our study concludes that economic benefits generally provide the primary incentive for land users to implement SLM practices to manage invasion by *P. juliflora*. However, even though prospects from economic benefits are the primary motivation for land users to implement SLM practices, the effectiveness of the SLM practices in managing invasion is a crucial determinant of land users' preferences. Therefore, SLM practices that are considered effective in managing invasion and likely to generate income for land users are more likely to be continuously implemented by land users.

The study further provides evidence that aspatial-temporal analysis of *P. juliflora* trajectories produces invasion dynamics, which can be linked to underlying land management decisions and their related drivers. Thus, land users' decisions to implement SLM practices are reflected in the spatio-temporal land cover trajectories. These trajectories of *P. juliflora* cover are helpful in designing sustainable management strategies by considering drivers that enable land users to manage invasion. This is because they produce invasion trends that can be related to their respective socio-cultural, economic, and environmental drivers.

Based on the steady increase of constantly invaded areas and decrease in constantly uninvaded areas, we conclude that prevailing management decisions are not sustainable in managing invasion. Lack of timely and accurate information to inform management decisions delays prompt management decisions and timely implementation of suitable management practices at the early stages of invasion. Likewise, land users will only implement SLM practices if their efforts are incentivized through supportive tenure rights, effective land governance institutions, and, most importantly, guaranteed direct economic returns.

The dominance of trajectory category 1 (constantly cleared) in agricultural areas and settlements implies that land users tend to concentrate their invasive alien species (IAS) management efforts in regions where abandoning those efforts would result in the highest income loss. Land users are more likely to actively manage invasion in areas where they are assured of benefiting from their efforts. Consequently, livelihood diversification away from land-dependent economic activities poses a challenge to the management of IAS on such lands. This situation puts communally shared resources, such as communal grazing lands, at significant risk of invasion since they are often abandoned as community members diversify their livelihoods beyond pastoralism. Initiatives aimed at reducing dependence on such parcels also diminish the commitment of land users to manage invasion in those areas. To effectively address this issue, management interventions should prioritize parcels that do not support ongoing livelihood transitions, particularly communal lands that are prone to constant invasion. Further, capacity building of local enforcement officers such as the chiefs is important in enhancing compliance with land management regulations. Failure to recognize and strengthen the capacity of such leaders limits the timely and efficient resolution of land-related disputes, which is a major setback to the implementation of SLM practices.

5.4. Recommendations

5.4.1. Policy recommendations

This chapter derives crucial recommendations from the study's findings to propel action-oriented progress in invasion management. For effective selection and implementation of Sustainable Land Management (SLM) practices, the involvement of land users in all stages of developing a management strategy is essential. Managing *P. juliflora* requires an integrated approach, considering various drivers to decide on appropriate land management options. In this regard, decision-making should involve a mixed-method approach, integrating spatial-temporal analysis of invasion patterns with ground-based surveys for accurate identification of relevant drivers. Further, holistic management approaches must incorporate scientists' empirical findings and recommendations based on context-specific spatiotemporal analysis.

Anticipating the implications of livelihood transformations is crucial for Invasion Alien Species (IAS) management, requiring government commitment and prioritization for practical balance. Government institutions should prioritize building community resilience to natural disasters, enhancing land users' potential and capacity for invasion management. Likewise, policies related to land management should incentivize livelihood systems promoting SLM practices, especially where direct economic gains are not expected. For instance, incentives encouraging the management of communally shared resources, such as pasturelands and roadsides, can promote the management of vulnerable yet neglected areas. Thus, policymakers should explicitly highlight guidelines translating into communal incentives for managing such neglected parcels.

Traditional land management practices play a significant role in managing communal grazing lands, and policies encouraging livelihood diversification from pastoralism should integrate sustainable customary practices. However, due to livestock's role in seed dispersal, studies integrating livestock production and environmental management against invasion should inform best practices.

The lack of timely knowledge among community members about the potential impacts of *P. juliflora* contributes to constant invasion, especially in densely invaded areas. Enhancing access to reliable and timely information on invasion's nature and impacts, along with the benefits of timely interventions, should be embraced across all invasion ranges. Researchers should proactively identify and address emerging research needs, and knowledge sharing between residents of densely and sparsely invaded areas will promote a timely response to invasion at the early stages.

Finally, strengthening local authority capacity by relevant parties, such as government and development institutions, will empower them to enforce tenure rights effectively. Local tenure rights enforcers should be trained on policies related to the customary tenure system and their roles in enforcing tenure rights. Further, government-led land demarcation will foster land-related dispute resolution and enhance SLM implementation. Additionally, formalizing the customary tenure system and communicating its provisions to local authorities and land users are vital for enforcing tenure rights at the communal level.

5.4.2. Recommendations for future research

Due to the extensive extent of the invasion process, there is potential to upscale and utilize spatial-temporal invasion trajectories of *P. juliflora* for broad-scale application to inform regional and national management strategies and test its applicability at a large scale. This approach can help identify priority areas that require management interventions and serve as a valuable planning tool to assess the spatial distribution of invasion patterns. By analyzing trajectory types, suitable management actions can be determined for larger spatial extents. However, it should be noted that conducting spatial analysis of *P. juliflora* trajectories can be resource-intensive and time-consuming, especially when dealing with larger areas or when time is limited. The initial analysis of raw satellite imagery to derive land cover classes adds complexity and duration to the process, as it requires the collection of ground-based control points (Mbaabu *et al.,* 2019). Moreover, since mapping *P. juliflora* is still a relatively new field of study, readily available pre-processed LULC data, including accurate mapping of *P. juliflora* cover, is unlikely to exist, further hindering the efficiency of the analysis. Further studies may therefore be needed to address this challenge and exploring alternative, more streamlined approaches. One promising avenue is the utilization of drones, which hold the potential for various benefits and faster outcomes compared to satellite image-based methods. Studies that investigate the capabilities and advantages of employing drones or other novel alternatives for this purpose are needed to yield quick nd reliable results over short periods.

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APPENDICES

Appendix I: Household Questionnaires

Management of *P. juliflora:* The Determinants of Land Users' Management Decisions and Practices in Marigat Sub-County.

Household Questionnaire

Introduction

For the fulfillment of my PhD study at the University of Nairobi, I am carrying out a study on institutional aspects to land tenure rights needed for successful implementation of sustainable land management (SLM) practices to sustainably control the spread of P. juliflora hence mitigating its adverse impacts on ecosystem services and human livelihoods. Your assistance in the provision of the relevant information needed to make this work a success will be highly appreciated. The information and data provided will be confidential and is intended for academic purposes only.

Section 1: Household Information and socio-economic factors

Sub-location name…………………………… GPS Coordinates……………….

Position in the household Household head [] Household member No. 1[]

A) Demographic information.

Gender	a)Male [] b) Female []
Age	a) Below 18 years [] b) 18-28 [] c) 29-39 [] d) 40-50 [] e) 51-60 [] f) 61 and above []
Highest education level	a) No Education [] b) Primary education [] c) Secondary education [] d) Tertiary education [] e) University education []
Household size	…………….. people
Main source of income	a) Farming [] b) Trading [] c) Pastoralism [] d) Bee keeping [] e) Any other (Specify)………………………….
Income from off-farm employment (USD)	a) 0-100 [] b) 101-500 c) 501-1000 d) Above 1000 f) N/A [ ] e.g. *no off farm employment*
Net	a) 10,000 and below b) 10,001 to 50,000

monthly household income in Ksh	c) 50,001 to 100,000	d) Above 100,000
No. of years lived in Baringo	a) Less than 5 years [] c)11 to 15 years [] e) 21 to 25 years [] g) more than 30 years []	b)6 to 10 years [] d)16 to 20 years [] f)26 to 30 years []

B) *To analyze the potential of stakeholder-led participatory processes in contributing to effective selection, implementation and chances of continued use of SLM practices.*

1) Have you ever tried to control the spread of *Prosopis*?

Yes [] No []

a) If yes, which practice have you applied and how effective has it been in controlling or preventing the spread of *Prosopis*?

Practice	**Purpose/intervention** Early detection and rapid response (EDRR) Prevention (P) Control (C)	**Effectiveness** Very effective (5) Effective (4) Moderately effective (3) Ineffective (2) Very ineffective (1)	**Follow-up actions eg removal of seedlings conducted** Yes (Y) No (N)
Uprooting and reseeding			
Uprooting and crop cultivation			
Cutting for charcoal production			
Chemical control			
Surveillance and removal of first invaders			
Any other			

b) On whose land did you carry out the SLM practice?

i) Own private land []

ii) Own communal land []

iii) Hired land []

iv) Other people's farms as a hired laborer []

v) Any other (please specify) …………………………………………………

c) How did you learn about the practice? ………………….…………………………………... …………………………………………………

d) What was the **main** reason that motivated you to implement the SLM practice that you learnt above?

i) Maximize economic benefits from the SLM strategy []

ii) Environmental protection []

iii) Socio-cultural welfare []

iv)Reduce/prevent further spread of *Prosopis* []

v) Any other [] ……………….

e) Which challenges, rating from the most (5) to the least (1) significant have you faced in implementing the SLM practice?

i) Lack of land ownership and land use rights []

ii) Lack of financial resources []

iii) Inadequate knowledge on implementation process []

iv) Availability of alternative sources of livelihood []

v) Inadequate support from relevant institutions [] ………………………………….

2) How would you describe your sub-location in terms of *Prosopis* coverage? (More than one response allowed)

i. Non-invaded []
ii. Under initial stages of invasion []
iii. Heavily invaded []

b) Following your feedback above, which *intervention* do you think will be most appropriate in managing *Prosopis* invasion in your sub-location?

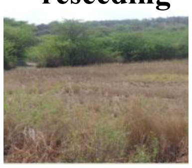
i. Prevention
ii. Early detection and rapid response
iii. Control
iv. A combination of (Specify) ……………………

c) Rank the following (selected) SLM practices from the best (5) to the least (1) suitable in meeting the indicated descriptions? (The first 3 tables are to determine whether they will prefer same practices for each intervention while the last one is to determine whether they will select SLMs selected by LIGS or those selected by scientists as suitable for the 3 sustainability dimensions)

Prevention of *Prosopis* invasion				
1. Surveillance of non-invaded areas				
2. Regulate grazing				
3. Fencing non-invaded areas (enclosure)				
4. Restrict movement of livestock to non-invaded areas				

Early detection and rapid response (EDRR) of *Prosopis* invasion			
1. Surveillance and uprooting			
2. Surveillance, cut stump below ground and burn			
3. Surveillance, cut stump below ground and backfill in grasslands			

Controlling *Prosopis* invasion			
1. Physical removal, area enclosure and grassland restoration			
2. Uprooting and crop production			
3. Cutting trees above-ground (for charcoal production)			

Description	Most cost effective SLM practice	Most likely to be socially accepted by community members	Most suitable in environmental restoration	Most preferred SLM practice
1. Uprooting and reseeding 				
2.Surveillance and removal of first invaders				

3. Enclosure to prevent invasion 				
4. Cut-stump treatment 				
5. Basal bark treatment 				

d) If given an opportunity, which of the above SLMs would you continuously implement on your farm?....................

e) Kindly give a reason for your choice above ……………….

i. Cost-effective []
ii. Effective in controlling *Prosopis* []
iii. Socially acceptable []
iv. Suitable in environmental restoration []
v. Any other []…………………………….

C) ***Implications of existing tenure regimes on the implementation of SLM strategies***

1)

Do you own land	Yes []	No [ ]

in Marigat?	
Estimated total size of all parcels of your land?	0- 5 acres [] 5-9 acres [] 10-14 acres [] 15 acres and above[ ]
Average walking time from your homest	30 min [] 31-60 min [] 1hr- 2 hrs. [] more than 2 hrs.[ ]

ead to your farm	
Type of land ownership	Individual [] Communal [] Freehold [] Leasehold [] Others (Specify
Number of employees	……………….
Main current land use /la	Natural vegetation [] Plantation forest Rain-fed agriculture Irrigated-agriculture [ ] Pasture [ ] Bare land [ ] *Prosopis* cover [ ] Any other [ ]
	Fully invaded [] About half the area is invaded Few isolated trees []

nd co ve r ty pe s on yo ur pi ec es of la nd	………………………………………………………………... ………… ………………………………………………
If th e cu rre nt m ai n la nd co ve r is Pr os op is, w	

hat is the level of invasion? What is the reason for *Prosopis* coverage above? Please explai	

n	
Main land use on the same pieces of land 10 years ago?	Agriculture [ ] Pasture [ ] Bare land [ ] *Prosopis* cover [ ] Any other [ ]
Causes of changes in the land use/l	……………..

and cover	
Tenure system	i)State owned tenure regime [] ii)Communal tenure [] iii)Individual tenure [ ]
Do you have a title deed?	Yes [ ] No [ ]

2) Which land rights related to the land tenure system do you *enjoy* as a land user?

Land right	Please tick if you have access to the land right
Rights of ownership	
Rights of *transfer* to others	
Rights of usage	
Any other…(please specify)	

b) Are there restrictions to the above mentioned rights limiting your ability to implement an SLM? Yes [] No []

c) If yes, please tick [] the relevant restrictions in the table below:

Land rights	Restrictions
Ownership rights	Land ownership is through male relation [] Restricted size of land to be owned [] Limited timeframe of ownership [] Any other [ ]
User rights	Allowable size of land [] Nature of land use [] Period of usage [] Any other [ ]
Transfer rights	Restricted persons to transfer to []

	Size of land transferable [] Lengthy procedure for transfer [ ]

3) Do you have any fears that you may lose your existing land rights in future?

Yes [] No []

b) If yes, then please explain why …………………………………………………………

4) Do you have any fears that your land rights may not be enforced?

Yes [] No []

c) If yes, then please explain why …………………………………………………………

5) Do you think access to land tenure rights in the area have an influence on the adoption and/or implementation of SLM practices?

Yes [] No []

b. If yes, please rate your feedback above on a scale of 1 to 5 below

Very negatively [1] Negatively [2] No effect [3] Positively [4] Very positively [5]

6) Which institutional arrangement is responsible for the enforcement of land tenure rights to ensure the community complies with them?

i. Household members []
ii. Community members []
iii. Local authority []
iv. County government []
v. National government []

7) Are there barriers to the enforcement of tenure rights needed for successful implementation of SLM practices on your land?

Yes [] No []

b. If yes, which ones?

i. Gender-based cultural biases []
ii. Inter and intra tribal conflicts []
iii. Weak institutional capacity []
iv. Any other []

c. Has there been an institutional setting which was favorable to SLM implementation aimed at *Prosopis* management and land restoration?

d. i) Yes [] ii) No []

e. If yes, could you please explain the main differences with the current situation? ………………………………………………………………………………………………

f. In your opinion, how can the institutional barriers best be addressed to enhance successful implementation of SLM strategies? …………………………….

8) Is there need to enforce existing land tenure rights in relation to making them more accessible to community members? Yes [] No []

Not sure []

9) Would you prefer a different institutional arrangement to take up this task?

Yes [] No []

b. If yes, then please indicate your preferred institutional arrangement.

i. Household members []
ii. Community members []
iii. Local authority []
iv. County institutions []
v. National government []

10) Which gender category plays a greater role in implementing SLM strategies?

Males [] Females []

b. What is the **main** reason for your feedback above?

i. Access to land ownership rights []
ii. Access to financial resources []
iii. Availability of time []
iv. Any other []

11) Do women have a right to own land in your community?

i) Yes [] ii) No []

12) In your opinion, are communally owned resources such as grazing lands efficiently managed?

i) Yes [] ii) No []

b) If no, what is your opinion on the reason behind this? ………………………
……………………………………………………………………….

c) Have you ever participated in the management of communally owned land/resource with an aim of restoring resources derived from them?

i) Yes [] ii) No []

d) If yes, what motivated you?

i) To get wood for charcoal production or other uses []
ii) To conserve the communal resource []
iii) A communal obligation []
iv) To restore communal grazing land []
v) Any other []

Appendix II: Institutional interview guide

MANAGEMENT OF *P. juliflora*: THE DETERMINANTS OF LAND USERS' MANAGEMENT DECISIONS IN MARIGAT SUB-COUNTY

A) Preliminary questions

Name of Institution …………………………………………………………….

Type of institution (Private sector, NGO, Government institution, CBO)

Respondent position..(optional)

Respondent age (optional) …………………… Respondent Gender ………………………

Respondent's residence period in the study area …….years

1) Does your institution have any direct or indirect mandate on the of enforcement of land tenure rights in this area? If yes, please explain?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………

2) Has your institution ever participated in motivating local community members to implement any form of SLM practice aimed at:
a) controlling *Prosopis* invasion? i) Yes [] No []
b) Restoring land cleared of *Prosopis* i) Yes [] No []

3) What is your take on community adoption and implementation of SLM strategies aimed at controlling invasion in terms of:
a) Main motivation for adopting and implementing SLM strategies

b) Challenges hindering implementation of SLM strategies

4) What is the role of land tenure rights in the implementation of SLM practices?

b. Is there a need to enforce land tenure rights to enhance implementation of SLM practices? If yes, how can this be achieved?

d) What are the barriers hindering the enforcement of tenure rights needed for successful implementation of SLM practices? What are the causes of the barriers and how can they be addressed?

Barrier to tenure rights enforcement	Causes of barriers	How to address the barriers

In your opinion which factors could be responsible for different patterns of *Prosopis* cover over the last 30 years?

Appendix III: A table summary of our types of data and sources

Layer	**Data type**	**Source**	**Date of access**
Land use and land cover	Classified raster layers	Woody weeds project (Mbaabu et. Al., 2019)	23rd April 2019
		Survey of Kenya (SoK), Japan International Cooperation Agency (JICA), and International Livestock Research Institute (ILRI). 1996. Digital Elevation Model created by ILRI and JICA, derived from SoK 1:250,000 Topographic Map	15th August 2020
Kenya SRTM 30 Meters raster data	Raster layer	Regional Centre for Mapping of Resources for Development (RCMRD) **http://geoportal.rcmrd.org/layers/servir%3Akenya_srtm30meters#more**	18th September 2019
Rivers,	Shapefile	World resources institute	1st

lakes, roads, and settlement	s	**https://www.wri.org/data/kenya-gis-data**	November 2019
Roads	Shapefiles	OpenStreetMap	
Population data	Shapefile	Centre for Training and Integrated Research in ASAL Development	3rd April 2021

Appendix IV: Photos collection during data collection

Appendix 3.3: Deliberative multicriteria evaluation process with a facilitator and participants (top) as WOCAT posters for different SLM practices are pinned on the wall to inform the process (bottom).

Appendix 3.4: Local actors during the participatory mapping process (A and B) and one of the outputs of the participatory mapping (C)

Appendix 3.5: The researcher administered a questionnaire to community members.

Appendix 3.6: One of the area chiefs being interviewed at his home. He holds a copy of SLM practice photos and descriptions to guide his responses.