IMPACTS OF INVASIVE ALIEN PLANT SPECIES ON PASTORALISM: A CASE OF NGORONGORO CONSERVATION AREA, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN NATURAL RESOURCES ASSESMENT AND MANAGEMENT

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CERTIFICATION

The undersigned certifies that he has read and hereby recommends for acceptance by the Open University of Tanzania a dissertation entitled: **“Impacts of Invasive Alien Plant Species on Pastoralism: A Case of Ngorongoro Conservation Area, Tanzania”** in partial fulfillment of the requirements of the degree of Master of Arts in Natural Resource Assessment and Management of the Open University of Tanzania.

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Dr. Cosmas B. M. Haule

(Supervisor)

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Date

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DECLARATION

I, **Dismas Cyril Macha**, declare that, the work presented in this dissertation is original. It has never been presented to any other university or institution. Where other people's works have been used, references have been provided. It is in this regard that I declare this work as originally mine. It is hereby presented in partial fulfillment of the requirement for the Degree of Master of Arts in Natural Resource Assessment and Management (MANRAM).

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Signature

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Date

DEDICATION

My work is dedicated to my beloved parents, the Mr. Cyril T. Macha and Mrs. Mary J. Chaky, who have established a strong academic foundation in my life.

ACKNOWLEDGEMENT

I am indebted to many people and organizations that made the completion of this study possible. My deepest gratitude goes to Dr. Cosmas Haule my supervisor, for his tireless supervision, valuable guidance, constructive criticisms and encouragement in developing my proposal and finally the dissertation.

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ABSTRACT

A study was conducted in three pastoral villages in Ngorongoro Conservation Area (NCA), namely; Olbalbal, Endulen and Kayepus to investigate the socio-economic impacts of increasing spread of invasive plant species. Mixed methods research design was adopted. Stratified random sampling was used to identify villages for social surveys. Socio economic data were collected through household interviews, key informant survey and focus group discussions. Diversity and abundance of livestock forage were assessed through field measurements based on standard procedures. Qualitative data was analyzed by content analysis while all quantitative data was analyzed by using different techniques in R statistical program. It was found that 90% of pastoralists recognized IPS in their villages. Livestock movement (80%) was reported being the major causes of spreading IPS followed by changes of weather condition (65%). Current means of controlling IPS include uprooting (40%) and burning (20%). Grass forage were more abundant (n = 34) and high diverse (H` = 2.01 to H` = 2.91) compared to herbs forage (n = 27) (H` = 1.77 to H` = 2.21) across all three villages. Additionally, nearly 70% of. grass indicated higher desirability compared to herbs forage species (20%), respectively. It is concluded that, although the current diversity and abundance of livestock forage are within the optimal levels to support large number of livestock, its future status is not guaranteed since the spread of invasive species could be higher beyond our expectation. Therefore, we recommend further studies in other affected villages within the NCA in order to obtain detailed information that could be used for management purpose.

Keywords: Alien species, pastoralism, Ngorongoro, Wildlife

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND ACRONOMY

ANOSIM	One Way Analysis of Similarity
H’	Shannon-Wiener biodiversity index
IMD	Inversion Melt Down
IPS	Invasive Plant Species
LGAs	Local Government Authorities
$\log_e$	the natural log of p_i
NCAA	Ngorongoro Conservation Area Authority
NCA	Ngorongoro Conservation Area
NGOs	Non-Governmental Organizations
NM	Nomadic Movement
p_i	proportion of *s* made up of the i^{th} species
R	Pearson correlation index
S	total number of species in the community (species richness)
SDGs	Millennium Development Goals
SPSS	Statistical Package for Social Scientists
UNESCO	The United Nations Educational, Scientific and Cultural Organization

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter provides a brief explanation of the specifics of the research conducted, its focus, the context of the study, the research questions, main argument presented and point out the importance of the study and key user of research findings.

1.2 Background to the Research Problem

Increasing population of invasive plant species raises concern about the sustainability of rangelands in most tropical countries (Obiri, 2011). Invasive plants species are very harmful and can reduce biodiversity integrity and cause dramatic detrimental environmental changes beyond restoration (Vavra et al. 2007). Similarly, they affect human and animal health, water resources and local livelihood (Ngondya et al. 2017; Shackleton et al. 2017). Degradation of rangelands has different implication to its productivity.

This includes decreased quality of forage, one of key elements that determine sustainability of livestock production such as amount of milk and meat yield (Holloway et al. 1979). Any form of disturbance that affects nutrition and feed supply system to livestock is known to affect their metabolic processes, immunity, reproduction and growth (Leng, 1990). It is suspected that the threat caused by IPS affect regional efforts to achieve millennium development goals (SDGs), particularly SDG1 (No Poverty); SDG2 (Zero Hunger); SDGs3 (Good Health and Well Being) and SDG13 (Climate action) (Cumming et al. 2017; Rao et al. 2010).

Today, IPS has been one of the major threats to management of natural and agro-ecosystem globally. Crop yield decrease, increased infections to crops and livestock and increased input production cost are some of major consequences. In Tanzania, the same problem has been reported in range land in the Ngorongoro Conservation Area (NCA) (Bukombe, Runyoro), one of exceptional biodiversity hotspot area in Tanzania (Homewood and Rodgers, 2004).

Range lands, inside and outside the crater, are potential pasture resource for Maasai pastoralists whose economy is currently depending on livestock only. Nearly 250,000 cows and 600,000 small stocks (goats and sheep) are estimated to coexist with wild animals (NCAA, 2019, un-published report). Rapid spread of invasive plant species is considered as one of potential threat to conservation in and livelihood of the Maasai in the ecosystem for example, in the dry season of 2002, three-quarter of the crater area was colonized, mainly by *Bidens schimperi* and *Gutenbergia cordifolia* (Estes & Henderson, 2002).

1.3 Statement of the Research Problem

Recently, the management of NCA has declared the rapid spread of invasive plant species both inside and outside the crater ecosystems. These species are considered as one of the potential threat to conservation in the ecosystem (Estes and Small, 1981). For example, in the 2002 dry seasons, three-quarter of the crater area was colonized, mainly by *Bidens schimperi* and *Gutenbergia cordifolia* and were reported to suppress population of palatable and high nutritive forages within the NCA ecosystem, like *Chloris pycnothrix* and *Brachiaria semiundulata* (Henderson, 2002). These species are preferred by both livestock and wild animals as forage resource, thus intensify competition between them. We suspect that, current spread of invasive plant species could have several socio-economic impacts to local pastoralists in the NCA, like reducing incomethat is generated from livestock products.

This suggests that the wellbeing of the Maasai in NCA is highly vulnerable unless invasive plants within rangelands are full controlled. Notably, conservation regulations at the NCA allow the Maasai to keep livestock only while other forms of land use, like cultivation, are strongly prohibited (Boone et al. 2006). Despite this problem, it is yet known how the current status of invasive species affects pastoralism in the NCA. Since invasive species are increasing at rapid rate, there is an urgent need for carrying a study on how invasive species affect local livelihood. This is because pastoralists' economy in the NCA have heavily inclined on livestock.

1.4 Objectives of the Study

1.4.1 General Objective

The main objective of this study was to determine the socio-economic impacts of invasive plant species to pastoralism.

1.4.2 Specific Objectives

(i) To examine the perceived causes of invasive plants in the range land.

(ii) To assess local efforts attempted to suppress invasive species in the range lands.

(iii) To evaluate the perceived knowledge on suitability of grass and herbs as forage to livestock.

(iv) To quantify the diversity of grass and herbs species in the range lands.

1.5 Research Questions

The study had the following research questions;

(i) What are the perceived causes of invasive plant species within the range lands?

(ii) What are the stakeholders` responses to management of invasive species?

(iii) What are the changes in the suitability status of invasive species?

(iv) What are the changes in the ecological status of invasive species?

1.6 Significance of the Study

The information collected from this study will be useful to different conservation stakeholders. The knowledge on causes and effects of invasive plants in the range land will be helpful to the Maasai pastoralists, livestock extension workers, health workers and the management of NCA. The identification of local efforts attempted to suppress invasive species will inform the Maasai pastoralists, researchers, and the management of NCA on how to select best practices for controlling IPS in the NCA. Information about suitability of grass and herbs as forage to livestock will guide pastoralists to establish grazing calendar and identify potential location for grazing. Understanding about diversity and distribution of grass and herbs species in the range lands will deepen the ecological knowledge of the NCA to park ecologists and other researchers.

It is expected that, the findings and recommendations raised from this study will contribute to various efforts dedicated to control spread of invasive plant species within the rangelands in the Ngorongoro Conservation Areas as well as sustaining local livelihood of the Maasai pastoralists.

1.7 Scope of the Study

The cover selected socio-economic parameters, in particular community perception and local knowledge on causes, effect and management of invasive species that are only found in rangelands. Additionally, the study mainly focused on the Maasai pastoralists because they are the main custodian of the range lands for many decades. Because of lacking other income sources to support their livelihood, this study has identified livestock as economic indicator that respond to changes in the status of invasive species within the range land.

The findings of this study will contribute to improving the decision-making process on daily management of rangeland within NCA. Also, sharpening various National conservation policies, that promote multistakeholder involvement in control of invasive plant species.

1.8 Limitations of the Study

This study has observed a number of issues that are important to be addressed. Documented information about the impacts of invasive species to livestock is still scanty in Tanzania, thus developing a basis for comparing findings of this study to other locations in the country remains a challenge. Only dry season data has been used in this study since a large part of the range land is not accessible during the wet seasons. The study generalized the effects of invasive plants to all livestock regardless of the categories, i.e., large and small stock. There is a possibility that the response of large cattle to invasive species would be different to that of goats or sheep.

1.9 Organization of the Study

This dissertation is comprised of six chapters. These include introduction, literature review, material and methods, results, discussion and conclusion and recommendation. Additionally, a total of four appendices have been included at the end of the document.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter provides an in-depth review on existing knowledge about the spreading of invasive plants in tropical range lands and their consequence to various socio-economic dimensions, the main emphasis being pastoral livelihood.

2.2 Conceptualization of Key Terms

Four key words have been applied in the title of this study, namely: socio-economic impacts, invasive alien species, pastoralism and conservation area. Notably, these keywords are cross-sectoral, thus involve diverse authorities, like conservation organization, local government authorities and ministries. To achieve sustainable land-based investments, like livestock domestication, number of stakeholders should be concerned with quality of land resources and how they are shared among different user groups, e.g. tourism industry, crop production, wildlife protection and water users. In the context of this work, Maasai pastoralism would not sustain without assessing how policies from other sectors are comprehended while practicing free extensive grazing. This minimizes number of socio-economic risks like conflicts or land degradation.

2.2.1 Socio-economic Impacts

The term socio-economic impacts, broadly refers to qualitative outcomes that confront an individual household or community after changes of a particular event, condition or policy. This could be caused by human or natural factors with noticeable change on social well-being (Etzioni and Lawrence, 2016). In this study, the term socio-economic impacts refer to implications of increasing invasive plant species to local livelihood quality, like decreasing income or deterioration of livestock health, in the Maasai pastoral community in the NCA.

2.2.2 Invasive alien species

Invasive alien plants are non-native plants that are introduced by man, accidentally or intentionally, outside of their natural geographical range into an area that are naturally not present (Weber, 2017) Normally, they affect negatively ecological processes and suppress population of native vegetation (Ismail et al., 2016). In this study, invasive alien plants refer to several grass and herb species that have invaded and colonized some parts of the natural rangelands in the NCA.

2.2.3 Pastoralism

Pastoralism is livelihood subsistence system practiced by nomadic communities whereby rangelands are extensively used livestock production through grazing (Dyson-Hudson and Dyson-Hudson, 1980). In this study, the term pastoralism refers to livelihood sustainability strategy where by the Maasai pastoralists in the NCA keep large herd of cattle, sheep and goats as sources of income, food and other cultural values.

2.2.4 Conservation Area

Conservation area is a location allocated by law for preservation of genetic or natural resources that could otherwise be vulnerable to anthropogenic activities (Watson et al., 2014). In this study, the term conservation area refers to the Ngorongoro

Conservation Area, the multiple land use area that is used for wildlife conservation, tourism activities and livestock keeping.

2.3 Theoretical Frameworks Review

A number of theories can fundamentally explain the expansion of invasive plant species. Nevertheless, not all can link well with extensive pastoralism in rangelands. To reflect interactions between the two key terms above, the invasion meltdown (IMD) and the nomadic movement (NM) theories are discussed.

In recent decade, there is increasing interest among ecologists to understand the patterns of plants community assembly and invasion across different natural habitats (Braga et al. 2018). This is attributed to the fact that, interactions among plant communities sometimes play a decisive role in regulating ecosystem structure and function (Soliveres et al. 2015). Ideally, positive interaction and complementarily among plants species is the central for sustainable landscape management. In a scenario where new invasion is allowed, alteration of species composition and ecological function may happen. This reveals that natural ecosystem exhibits resilience limits.

2.3.1 Invasion Meltdown Theory

To concur with this phenomenon, we suggest the theory of invasion meltdown theory (IMD) being appropriate to occurring changes in ecosystem when new invasion remain uncontrolled. The theory has the following two major assumptions; negative interactions have been suggested as barrier for species to arrive to new habitat and the second state that positive interactions among non-native species could facilitate one another interaction (Simberloff and Von Holle, 1999). The theory is acknowledged for being a powerful one because of its wide applicability across different natural habitats (Simberloff and Von Holle, 1999). For example, D'Antonio and Chambers (2006) have found that infected natural ecosystems will not be capable of withstanding expansion of invasive species forever. Beyond certain thresholds levels, any further invasion would expand at exponential rate. In this proposed study, the IMD theory would provide some highlights on understanding ecological pathways that invasive plant species colonized rangelands and replaced the native species.

However, the IMD could have some limitations in this study. It is difficult to apply this theory to predict future scenarios of invasion process. For example, to what extent the native forage species would be replaced after certain period of time. Since natural antagonism exists among plant communities, it is not yet known to what extent these facilitative effects of non-native species occur (Braga et al., 2018).

2.3.2 Nomadic Movement Theory

The nomadic movement theory (NM) can be usefully applied to describe linkages between biotic and biotic factors that drive pastoral movements. The emergence of this theory is rooting on the fact that availability of enough pasture or water varies at different seasons of the year to enhance avoidance of rangelands that has been seriously affected by invasive plant species or livestock diseases vectors (Smith, 1992). The main assumption of NM theory is that interplay that exists between animal behavior and herders skillful action to maintain herd cohesion and minimize hazards (BurnSilver et al., 2004). Therefore, it provides a very broad picture about struggles for sustainability of pastoral economy (Dwyer and Istomin, 2008). In this proposed study, the expansion of invasive species could be among ecological factors that would severely affect livestock health and pastoral livelihood. Thus, influence decisions of pastoralists to relocate to new habitats where rangelands could provide palatable and high quality forage for their livestock. However, this theory does not explain how drivers of movement interact one another (Dwyer and Istomin, 2008). Such information could be very useful to guide conservation managers or policy makers when suggesting mitigation measures.

2.4 Empirical Literature Review

2.4.1 Importance of NCA to Conservation and Local Livelihood

The Ngorongoro Conservation Area (NCA) was established and gazetted in 1959 as a multiple land use to protect valuable wildlife biodiversity while sustaining livelihood of Maasai people (Homewood and Rodgers, 2004). Apart from being a biosphere reserve, the NCA is also recognized as a World Heritage Site and the International Biosphere Reserve (Masao et al. 2015). The 8292 km^2 of the NCA include the Crater area, the world’s largest inactive, intact, and unfilled caldera.

The grassland in the crater floor and the forest rim offer diverse habitats for several species of fauna and flora which are resident within the NCA and adjacent protected areas, like Serengeti National Park, Loliondo Game Controlled Area and Maswa Game Reserve (Runyoro et al. 1995). Apart from maintaining genetic diversity, diverse wildlife population within the NCA has been the major tourist attraction within that benefit the country and local community to generate revenues (Charnley, 2005). Concurrently, the extensive grasslands located inside and outside the crater have been potential pasturelands for Maasai livestock. Indeed, according to regulations of the NCA, other forms of land use, like cultivation, are strictly prohibited among local residents (Boone et al. 2006). This justifies the importance of livestock to the Maasai in the NCA. Until 2018, nearly 250,000 cows and 600,000 of small stock (goats and sheep) are estimated to coexist with wild animals (un-published report, NCA, 2019).

Moreover, rangelands provides number of co-benefits which include mitigation of climate change effect through effective sequestration of greenhouse gases and nature based tourism (O'Mara, 2012). In multiple land use ecosystem, like the NCA, rangelands are the heart of pastoral economy that has been practiced under traditional management systems for decades (Homewood et al. 2009). Equally, rangelands sustain food security and a broad market chain that involve communities outside the rangelands (Salih, 1993).

2.4.2 Invasive Plant Species and their Impacts to Range Lands Quality

The importance of rangelands to nutrition of livestock and wild animals is highly threatened by increasing population of invasive plant species. The presence of invasive plant species in rangelands affects diversity, distribution and abundance of native plant species. These changes are attributed to cause suppression or completely extinction of some valuable forage species at local or regional levels (Dickson et al. 2012).

For example, invasive plants species are claimed to affect water quality and quantity in South Africa (Chamier et al. 2012). Nearly 1.44 billion m^3 of water is lost annually, the amount which is equivalent to water demand of 3.38 million households annually or to irrigate 120 000 hectares of cropland (WWF, 2016). Invasive plant species are reported to affect feed abundance and health of animals too. In Laikapia Country in Kenya, invasion of *Opuntiastrica* resulted to reduction of 50-75% of valuable grass land and cause ill health and death to livestock. In the same area, households experience economic losses worth between US$500-1000 per year (Shackleton et al. 2017). Likewise, (Obiri, 2011) observed key invasive plant species that cause death of livestock by poisoning and destroying livestock foliage, accelerating biodiversity loss via suppression of native plants.

Conversely, the direct effects of invasive plants species to human health have been much less analyses. Nonetheless, they can cause wide range of impacts such as psychological effects, phobias, allergies, poisoning, bites, disease and even death (Mazza and Tricarico, 2018). Indirectly, invasive plants may be provide potential habitat for diseases vectors, like mosquitoes and other insects that carry ailments like nagana and sleeping sickness(Muller et al. 2017).

It is suspected that the threat caused by invasive species affect regional efforts to achieve millennium development goals (SDGs), particularly SDG1 (No Poverty); SDG2 (Zero Hunger); SDGs3 (Good Health and Well Being) and SDG13 (Climate action) (Cumming et al. 2017; Rao et al. 2010). However, extracts from some invasive species have number of economic advantages. For example, plant-derived products are increasingly being used to combat crop pests because they are natural and are often assumed to be safe for the environment. Extracts of *Tagetesminuta* can be used as insecticides, fungicides, and nematocides (Thembo et al. 2010; Weaver et al. 1994).

2.4.3 Causes of Spread of Invasive Plants Species

Climate change, land use change and transport vector interact in a complex way that favor the spread of invasive plant species in various ecosystems (Crowl et al. 2008). Towards effective control of invasive species, there is a need of identifying the invasion hotspots. However, this needs to establish a network of stakeholders like local farmers, pastoralists and local government authorities (Lodge et al. 2006). Citizen science may be useful to report on new invasion and environmental or health changes related to invasion (Gallo and Waitt, 2011).

Indeed, spread of invasive species differ across gradients of climate and land use (Crowl et al. 2008). Therefore, a clear protocol that is customized according to local settings is a necessary consideration. The increased travel and weak quarantine programs in most Sub-Saharan countries (Thresh, 2003), is especially vulnerable to invasion of plants.

2.4.4 Control and Management of Invasive Plant Species

In most developing countries, community involvement in control of invasive plant species is hindered by number of factors. Lack of awareness about harmfulness of these species is attributed to poor access to extension education among local farmers (Obiri, 2011). Additionally, control of invasive species could demand adequate resources, especially manpower. However, labor availability from youth could be a problem following increased urban migration. Concurrently, majority of rural people have very low income to spare for hired labor (Farrugia, 2016). Most of attempted efforts to control invasive plants include traditional approaches which are generally not efficient in terms of time consumed and amount of plants removed (Ngondya et al.

2017). This includes physical uprooting, slashing, burning and occasionally chemical spraying (Manning and Miller, 2011). Additionally, more studies are being conducted to determine how the knowledge of soil-plants interactions can be applied to control invasive species. For example, by adjusting different levels of exchangeable soluble bases in the soil could bring positive results on controlling *A. Mexicana* and *T. minuta* in favor of native species (*Weidenhamer and Callaway, 2010*).

2.5 Conceptual Framework

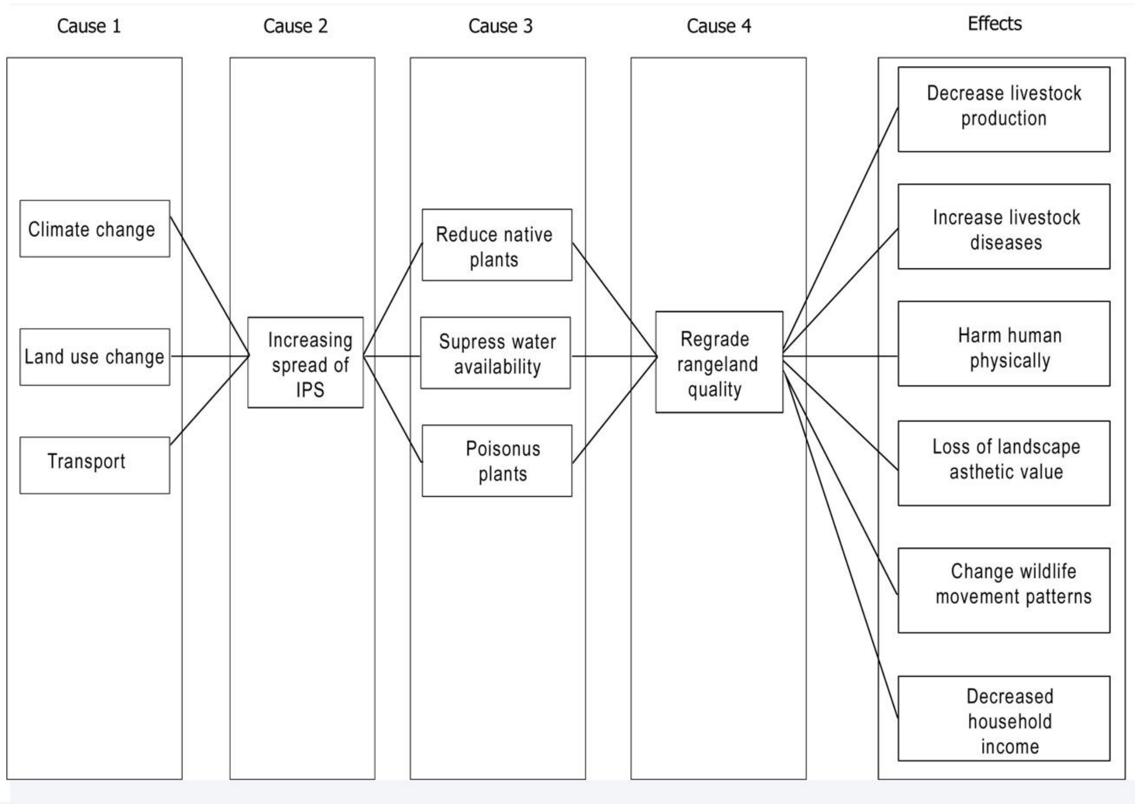

Figure 2.1: Conceptual Framework

The conceptual framework above is comprised of a series of boxes that indicate how a various factors influencing spread of invasive species can interact differently and lead to diverse outcomes that affect services derived from rangelands. Causes 1 are primary drivers that influence spreading of invasive species. Under poor control mechanism, high population of invasive species (Cause 2) could affect distribution of native plants and water availability. Combination of these effects (Cause 3) could suppress rangeland quality. Ultimately, the severely degraded rangeland (Cause 4) is a source of diverse social-economic and ecological consequences.

2.6 Research Gap

The relationship between performance of pastoralism and current spread of invasive plants in NCA has not yet been well clarified. Thus, it is not obvious to suggest best management options that will help pastoralists to improve productivity of their livestock. Therefore, the purpose of this study was to determine the impact of invasive alien plant species on pastoralism and assess the adaptive measures attempted to control the problem.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

This chapter provides a detailed account of the study design, study area, data collection procedures, and the statistical methods used in data analysis.

3.2 Study Area

The Ngorongoro Conservation Area (NCA) is located in the western side of Arusha region, in the Ngorongoro district. It borders the Monduli district on the East, Karatu district on the South and Mara Region in the west. The most prominent tourist and geological feature of the NCA is the crater, the world largest intact volcanic caldera. The NCA is a multiple land use covering 8,292 km^2 area important for wildlife conservation, livestock keeping and settlement for the Maasai pastoralists (Sinclair and Arcese, 1995). Given its unique geomorphology and biotic integrity, the NCA is recognized as one of UNESCO World Heritage site, Man and biosphere reserve and one of African seven wonders (Masao et al. 2015).

The NCA experiences bimodal rainfall patterns whose distribution is highly influenced by topography. Three major habitats characterize the area, namely; short grass plains, highlands and the crater (Kabigumila, 1993). The highland Forest Reserve and the crater receive between 800 and 1500mm of rainfall per year while the foot of the NCA and the Gol mountains receive below 500mm per year. A topo sequence of several soil groups are found from grassland to crater bottom (Anderson and Herlocker, 1973). Major vegetation types in the NCA include grassland, forest, bushland, shrubs and swamps patches (Kabigumila, 1993). This study was conducted in three villages, namely: Olbalbal, Kayapus and Endulen (Figure 3.1) which are among the most affected locations with invasive plants in the NCA (NCAA, 2019, un-published report).

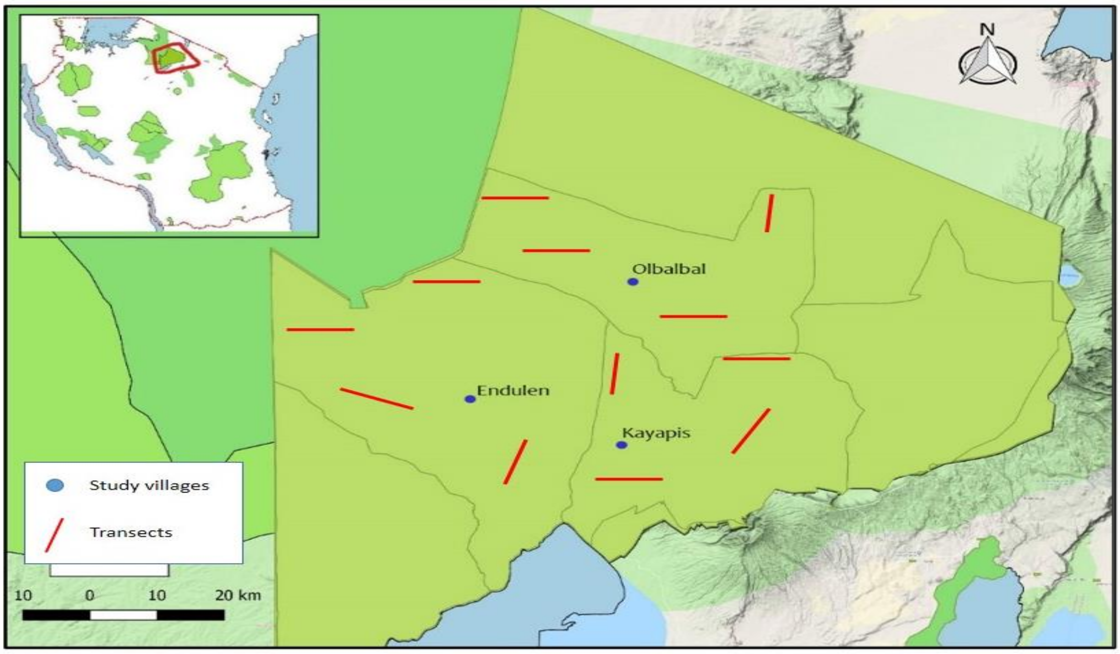

Figure 3.1: A Map of the NCA showing the Locations of Study Villages and Transect Line

Source: Google Maps, (2020)

3.3 Study Design and Approach

A cross-sectional study design was applied during data collection of this study. Both socio-economic and field surveys were conducted at the same time of the year. Additionally, the study aims to relate information from households and that obtained in the field.

This study adopted a mixed methods research approach combining both qualitative and quantitative approached, as the study demanded information from multidisciplinary angles. Stratified random sampling was used as sampling procedure. All villages that practice livestock keeping were identified. Then, villages that were affected by IPS were isolated from the rest. All villages that were accessible throughout the year were identified. Finally, three villages were randomly selected from the list.

3.4 Sample Size and Sampling Procedures

Data for this study involve mainly interview methods and field surveys. The former involves household interviews, focus group discussions (FDGs) and key informant meetings (KIIs). The later involve field measurements to collect ecological information from range lands.

Purposive sampling (Tongco, 2007) was used to obtain representative households for household interview. This targeted villagers who indicated reasonable awareness about invasive plants, and also showed willingness to be interviewed. With the help of village leaders 20 households were from each of the three villages were selected, thus making a total of 60 households.

Focus group discussion (FDG) involved between 8 and 10 villagers who are known to be highly affected by invasive plant species. Additionally, KKIs involved one to one consultation with selected members of community for detailed discussion on particular subjects.

3.4.1 Sources of Data

Primary data for this study generated from interviews and field surveys as stipulated above. Additionally, the study gathers secondary information from various sources, like published research papers as well as unpublished reports from village, district and project offices.

3.4.2 Data Collection Instruments

3.4.2.1 Collection of Socio-economic Information

Socio-economic information was considered necessary for this study because it enhances researchers to characterize how pastoral communities are sensitive, assess their adaptability capacity and understanding vulnerability of social systems in relationship to increasing dominance of invasive plants within the range lands.

Three major approaches to collect socio-economic information:

(i) Household Interviews

Household interviews were conducted to 20 households from each of sampling village, making a total of 60 participants. A structured questionnaire was used as a tool for data collection. Household interviews aimed to meet the following; determine socio-economic status of the households, assess community awareness about invasive plant species and impacts to livestock. Also, to examine whether community has any future strategies to overcome impacts caused by spread of invasive plant species. All questions were asked in Kiswahili and recorded in English. Where a respondent understands only the *Kimaasai* language, an interpreter from the same village was sought. A sample of questionnaire is attached as appendix 1.

(ii) Key informant interviews

These meetings were conducted in order to obtain in depth understanding of prevailing problem of invasive plant species in the range lands and future strategies for avoiding further impacts of IPS. Few people were contacted for these discussions, particularly ecologist from the NCAA and village leaders. If necessary, selected elderly villagers who demonstrated good knowledge about invasive plant species were contacted. A checklist of question (Appendix 2) was used to guide discussions.

(iii) Field survey

This exercise was conducted for two purposes. Firstly, to determine variation of forage palatability and secondly to quantify diversity and distribution of forage species.

At least 5 experienced pastoralists in each village were involved in identification of grass and herb species desirable to livestock as feed. This is based on their day-to-day experience with the response of livestock and characteristics of plants within the range lands. Total of five 1km long transects were established in pastureland in each village. Research team identified spots where livestock normally forage. Animals were pushed away to allow observation exercise to be conducted. Sampling quadrants (2m by 2m) were established at an interval of 20m (Figure 2), thus making a total of 25 sampling points in each village.

(iv) Determine pastoralists` perceptions and awareness about invasive species

Socio-economic surveys were conducted in order to understand the knowledge level and sensitivity of pastoralists to increasing levels of invasive plants species in the rangelands. Participatory approaches through different data collection tools were used, namely: household interviews and key informants (KIIs) meetings. Interviews with household heads, (n = 20) from each village were conducted by using structured questionnaires (Appendix 1).

Thus, makes a total of 60 households in the entire study area. All questions were asked in Kiswahili or Kimasai language and recorded in English.

Key informants (KIIs) meetings (n=10) involved discussions with ecologists from the NCA, district staff and selected village heads. KIIs meetings aimed to understand involvement of institutions in management of invasive species in the NCA. Set of questions was used to guide discussion with KIIs (Appendix 2). Before start the meetings, the informed consent procedure was followed to ensure participant about their identity and confidentiality.

(v) Diversity of forage species within range land

Sampling quadrants, measuring 2 m by 2 m, were established at an interval of 20m within 1km long transect. Thus, makes a total of 25 sampling points in each village. Two major activities were conducted during field survey. The first one was identification of palatable forage suitable for livestock feed. The other one involved quantification of abundance and diversity of the most suitable forage for livestock in the range lands.

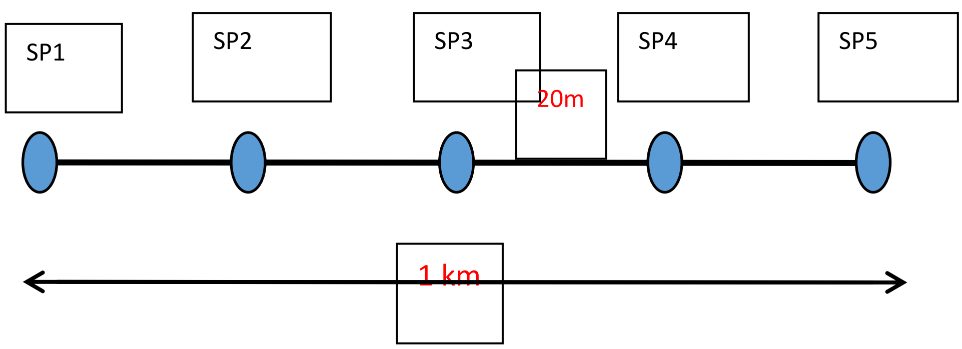

Figure 3.2: Transect Layout for Field Data Collection

Citizen science was applied whereby a protocol to engage local community in data generation was established. Between 5 and 10 experienced pastoralists were involved in identification of grass and herb species perceived desirable feed to livestock in range lands.

Quadrants were laid as described above. All palatable forage and invasive species were identified, counted and recorded in the data sheet. The suitability level of all plants within the quadrant was assessed and documented. Patterns of vegetation richness and diversity were assessed by using Shannon-Wiener Diversity index (Kent and Coker, 1992) as shown in the formula below:

$$H = -\sum_{i=1}^{s} p_i \log p_i$$

Where:

H' = the Shannon-Wiener biodiversity index

$\log_e$= the natural log of p_i

s = total number of species in the community (species richness)

$\boldsymbol{p_i}$ = proportion of *s* made up of the i^{th} species

Moreover, the index of dominance (ID) was used to measure the distribution of individual among the species in a community (Ambasht, 2001).

3.5 Data Analysis

Content analysis was used to analyze qualitative information, like verbal discussions during households and KIIs meetings. This analysis involved transcribing, identify the key themes and coding them (Hennink, 2013). Pastoralists' information about forage suitability was ranked into four levels as follows: (i) Highly desirable (ii) desirable

(iii) less desirable, and (iv) undesirable. Additionally, we classified observed forage species into two classes; edible and non-edible. To determine the status of forage diversity and abundance, Shannon Diversity Index was used. All qualitative information was analyzed in Statistical Package for Social Scientist (SPSS, version 16.0).

3.6 Ethical Considerations

This study gave a consideration of the following ethics:

Informed consent: Prior to starting data collection, it was ensured that the targeted participants (villagers and key informants) understand well the purpose of this research.

Confidentiality and anonymity: Respondents were ensured that their answers and identity will be kept confidential and used only for this study.

Potential of harm: To avoid physical harm during field data collection, armed ranger accompanied research team especially when working closer to dangerous wild-animals. Moreover, social surveys involved friendly approach to avoid psychological stress or harassment to interviewees.

Communicating results: Bad practices like plagiarism and academic fraud were avoided during preparation of this work.

3.7 Validity and Reliability

According to Kothari (2004), the term validity refers to “the extent to which a test measures what we actually wish to measure”. It is the trustworthiness and accuracy of instruments, data, and the findings in research. In any study, validity depends on the research instruments used for data collection and analysis. Reliability is defined as "the accuracy and precision of a measurement procedure. It indicates the degree to which an instrument measures what it is supposed to measure" (Kothari, 2004). It is the stability and consistency of the measurement used, which ensure that each time it is used it is capable of yielding the same results.

In ensuring validity and reliability of findings, multiple methods were used in data collection, analysis, and presentation in this study. The use of multiple methods was useful in enriching each other, thereby supplementing the drawbacks of one another. The use of multiple research methods was also important for triangulation. Methods used in this study can be used in similar studies elsewhere. After the preparation of research instrument, pre-test or pilot study was undertaken. Pre-testing was inevitable for identifying and rectifying shortcomings in the instruments, and addressed them before the actual data collection undertaken. Research instruments were translated from English to Vernacular Masai language. The feedback was good. Additionally, these were shared with my supervisor about all process of conducting the trials.

CHAPTER FOUR

FINDINGS

4.1 Overview

This chapter presents key findings of this study which cover the following areas; (i) Local perception and knowledge about invasive species, (ii) Factors influencing their spread, (iii) control and their management (iv) future strategies to avoid further impacts of invasive species (iv) status of livestock forage in the study villages (v) forage diversity in the range land.

4.2 Local Perceptions and Knowledge about Invasive Plant Species

Pastoralists' perceptions about the effect of invasive plant species in range lands were different across the three villages (Fig. 4.1). Not more than 5% of respondents from the study villages considered invasive plants species being nutritious feed to livestock.

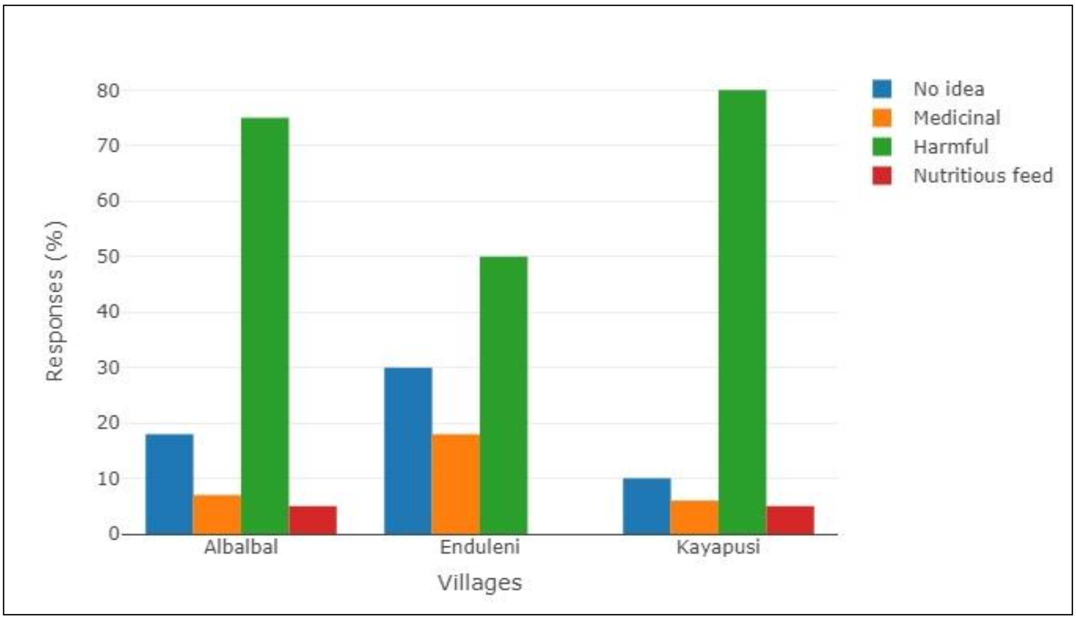

Figure 4.1: Importance of IPS Across Different Villages

Source: Field survey, 2020

In contrary, the majority of villagers (above 50%) from all three villages revealed that invasive species are very harmful to both livestock and human health. Less than 5% of villagers from Kayapus and Olbalbal did not recognize medicinal value of invasive plants. However, nearly 20% of villagers in Endulen agreed that some invasive plants could be useful herbal medicine.

In addition, the knowledge about invasive species was also variable among pastoralists. We noted number of villagers who did not understand about the importance of invasive species to livestock, majority (31%) being from Endulen village. Likewise, villagers had different memories regarding time when invasive species became a problem in their villages (Table 4.1). The majority (>50%) mentioned between the last 5 to 10 years. Nearly 20% remembered invasive species to occurred more than 20 year ago while very few (<5%) thought that invasive species have invaded pasture land in the recent 5 years.

Table 4.1: Percentage Time when IPS was Noted in Pasture Lands

Village name	Less than 5 Yrs	Between 5 and 10 Yrs	Between 10 and 20 yrs	Above 20Yrs
Kayapusi	4	68	10	18
Endulen	3	57	19	21
Albalbal	3	64	14	19

Source: Field survey, 2020

Furthermore, we noted that the local knowledge about the implications of IPS to livestock and human health was variable across villages (Table 4.2). Milk yield, weight loss and diarrhea were reported by more than 50% of respondents. Poor fertility varied greatly across villages whereby responses from Olbalbal were nearly twice that reported from Kayapusi and Endulen. Dizziness was the least reported (<10%).

Table 4.2: Percentage Distribution of the Effects of Invasive Plants Species to Livestock Health

Village	low milk		weight loss		Stunted growth		Poor fertility		Diarrhea		Dizziness	
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Kayapusi	55	45	75	25	20	80	20	80	65	35	5	95
Enduleni	65	35	90	10	10	90	25	75	60	40	5	95
Albalbal	90	10	90	10	40	60	40	60	70	30	9	91

Source: Field survey, 2020.

On the other hand, more that 50% of villagers did not realize any effect of invasive species to humans (Table 4.3). Nearly 15% of respondents agreed that invasive species cause skin itching to people while nearly 25% mentioned physical injuries being a problem.

Table 4.3: Percentage Distribution of the Effects of Invasive Plant Species to Human Health

	Itching (%)	Bad smell (%)	Injuries (%)	No effect (%)
Kayapusi	14	5	43	33
Enduleni	5	0	40	55
Olbalbal	10	0	25	65

Source: Field survey, 2020.

4.3 Factors Influencing the Spread of Invasive Species in Pasture Lands

Results of major causes influencing the spread of invasive plants species in the pasture land are reported in Figure 4.2 From the results, it is shown that changes of weather condition was the most important factor in Kayapusi village (13 %) while movements of livestock from one place to another was significant in Endulen and Albalbal villages (16 %). The influence of tourists visiting the NCA and surface flow of rain water were reported by a very small proportion of respondents, revealing to have a little contribution to the spread of invasive species in the study villages.

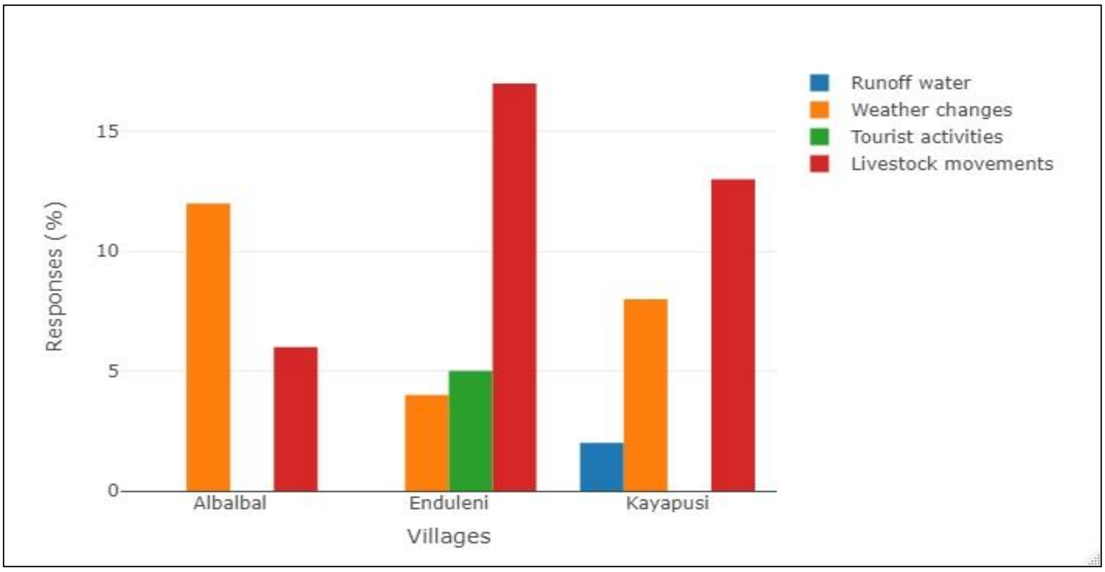

Figure 4.2: Spatial Variation of Factors Influencing Spread of Invasive Species in Study Villages

Source: Field survey, 2020

4.4 Control and Management of Invasive Species around the NCA

Results of methods used to control invasive species in the NCA are reported in Figure 4.3. The results show that the majority of the respondents in all study villages were not attempting to control invasive species within the pasture land. Furthermore, the results indicate that uprooting of invasive species was an important control method in Kayapusi (25%) followed by burning (15%). Similarly, uprooting was reported by 30% of the respondents in Endulen compared to 20% who practice burning. Slashing invasive species was more practiced in Olbalbal (10%) while the use of chemical control method was not reported from any village.

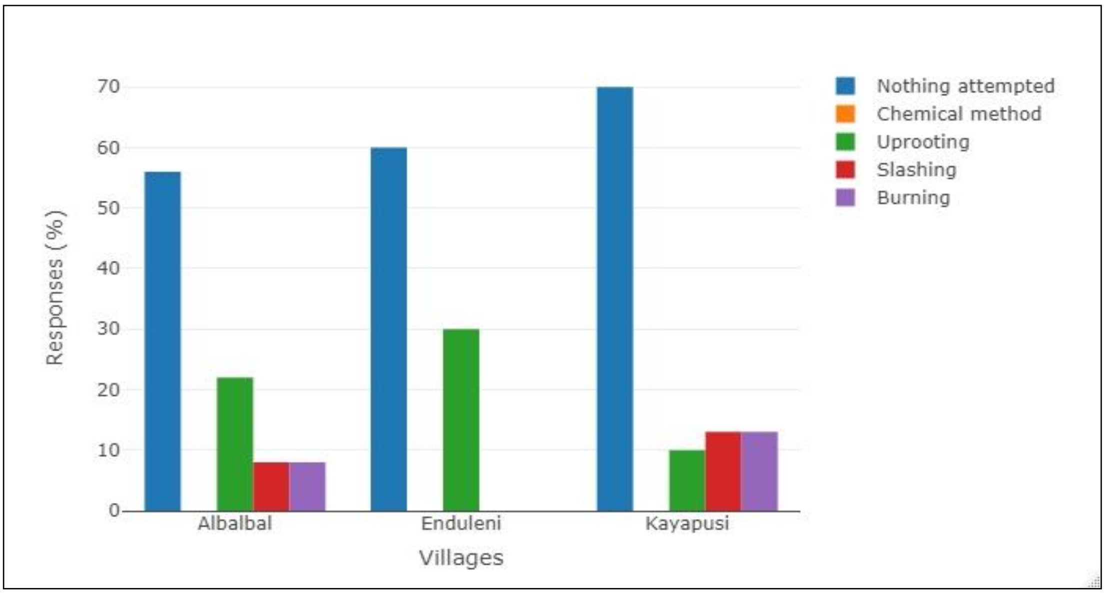

Figure 4.3: Spatial Variation of Methods used to Control Invasive Plants Species in Study Villages

Source: Field survey, 2020

4.5 Livestock Forage Quality, Diversity and Abundance

4.5.1 Forage Desirability and Edibility

The results of community perceptions on forage desirability as livestock feed are presented in Table 4.4. It was noted that between 6% to 70% of known grass species indicated desirable traits as livestock forage while less than 30% were less desirable.

Table 4.4: Distribution of Grass and Herb Desirability in the Study Area

Locations	Highly desirable (%)		Desirable (%)		Less desirable (%)		Undesirable (%)	
	Grass	Herb	Grass	Herb	Grass	Herb	Grass	Herb
Kayapusi	15.7	0	69.6	16	8.7	41	6	47
Enduleni	5.4	2	65.2	18.8	28.4	24.2	1	55
Olbalbal	7.8	0	72	20.5	19.2	36.2	1	43.3

Source: Field survey, 2020

All three surveyed villages indicated nearly similar response on grass desirability. In contrary, herb species were negatively perceived being desirable feed resource to livestock (25% -55%). Hardly 20% of respondent perceived herbs being desirable forage to livestock.

Furthermore, the respondents' view on forage which was edible to livestock is reported in Table 4.5. The results (Table 4.5) show that nearly all grass species were edible while more than 50% of herbs were not edible. Focused Group Discussion with pastoralists indicated that some invasive grass and herbs species like Makutian (*Eleusinejaegeri*) are consumed by livestock during critical shortage of pasture. Similarly, in-depth interview with Livestock Officer from Ngorongoro District Council indicated that livestock prefer to feed in new locations than before.

Table 4.5: Distribution of Grass and Herb Edibility in the Study Area

Locations	**Grass**		**Herbs**	
	Edible (%)	**Not edible (%)**	**Edible (%)**	**Not edible (%)**
Kayapus	98	2	33.5	66.5
Endulen	95	5	40	60
Olbalbal	97	3	42.5	57.5

Source: Field survey, 2020

4.5.2 Status of Forage Diversity and Abundance

Grass forages indicated higher diversity compared to herbs across all three study villages. The most abundant grass and herbs species are shown in Plate 4.1 and Plate 4.2, respectively.

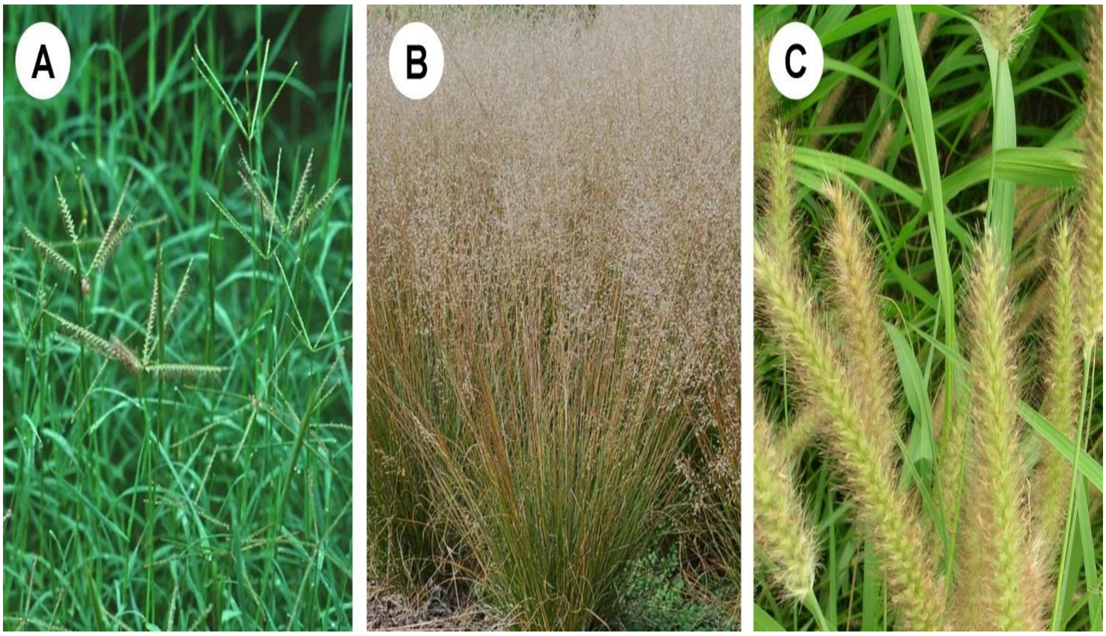

Plate 4.1: Three most Dominant Grass Species in the Study Area

Cynadondactylon* (A), *Sporobolusloclados* (B) and *Penissetummezianum (C)

Source: Field survey, 2020

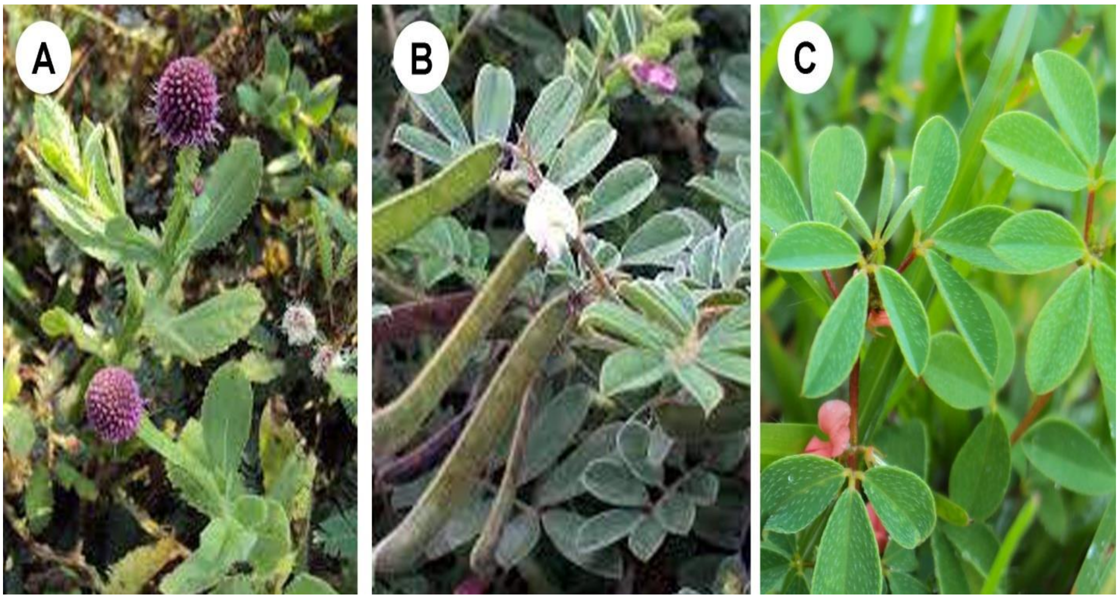

Plate 4.2: Three most Dominant Herbs Species in the Study Area

Sphaeranthuscyanthuloides* (A), *Tephrosiapumila* (B) And *Sphaeranthuscynanthuloides (C)

Source: Field survey, 2020

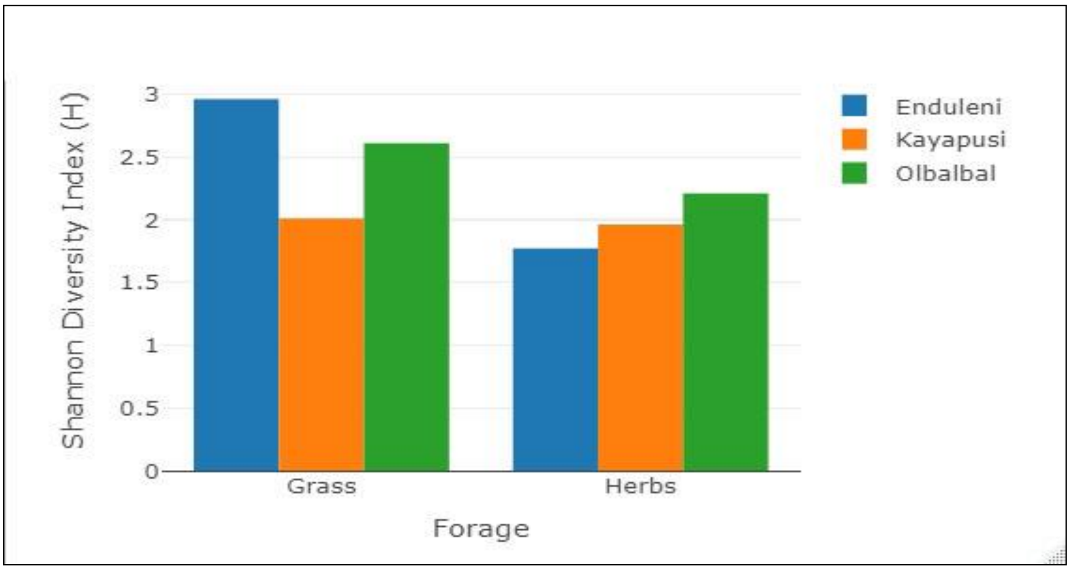

Figure 4.4: Variation of Grass and Herbs Species Diversity Found in the Study Area Based on Shannon Diversity Index

Source: Field survey, 2020

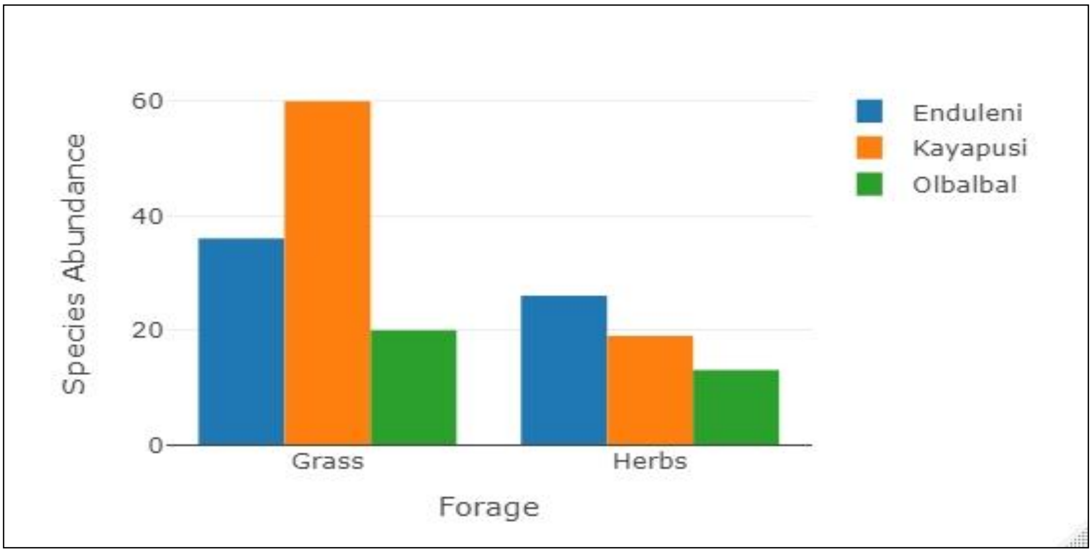

Figure 4.5: Species Abundance of Grass (A) and Herbs (B) Forages Found in the Study Area

Source: Field Survey, 2020

Shanon Diversity Indices (H`) for grass species were 2.96, 2.01 and 2.61 in Endulen, Kayapus and Olbalbal villages while herbs species indicated 1.77, 1.96 and 2.21 in

Endulen, Kayapus and Olbalbal villages (Figure 4.5). While Endulen village had highest diversity of grass species, it scored the lowest for herbs species. In Kayapus village diversity of grass and herb were nearly the same while a slight increase in grass compared to herb diversity was noted in Olbalbal.

The abundance of grass species were 36, 60 and 20 in Endulen, Kayapus and Olbalbal villages while herbs species indicated 26 19 and 13 in Endulen, Kayapus and Olbalbal villages (Figure 4.6). The highest grass abundance was observed in Endulen village while Olbalbal villages indicated the lowest. Moreover, herbs abundance was twice in Endulen compared to Olbalbal.

4.6 Summary of the Chapter

Pastoralists perceived invasive plants being less nutritious feed resources harmful to human and livestock. Major drivers that influence spreading of invasive plant species across the study villages ware reported differently. Only fewer methods, uprooting and burning, are attempted by pastoralists to control invasive plants. Pastoralists agreed that rangeland still offer desirable forage for their livestock. However, most of herbs were not preferred compared to grass species. Similarly, grass indicated higher species diversity compared to herbs across all study villages.

CHAPTER FIVE

DISCUSSION

5.1 Overview

This chapter provides a synthesis of results as follows; (i) Local knowledge about invasive species (ii) control of invasive species, (iii) forage quality in range lands (iv) diversity and abundance of forage species.

5.2 Local Knowledge about Invasive Species

It seems that pastoral awareness about invasive species and implications to livelihood is more or less similar across all three study villages. pastoralists could have been aware of invasive species for the last two to three decades around NCA. However, the problem seems to increase in recent years. Decreasing animal production was considered serious problem compared to signs of animal illness. Probably, livestock production impacts directly pastoral economy as they have limited options to sustain livelihood. Moreover, the importance of invasive species as forage could be associated with scarcity of forage during dry season. Recent studies have indicated that rainfalls have decreased in NCA (Leweri et al. 2021).

Notably, most invasive species, like Makutian grass, are resistant to drought. Thus, enable livestock to survive before next rains. Increasing concerns about the negative impacts of invasive plant species to livestock health has been reported in other rangelands in East Africa. Unpalatable forbs and sedges have dominated the herbaceous vegetation of the degraded open rangelands around Lake Baringo Basin in Kenya (Verdoodt et al. 2010). Likewise, increasing spread of non-native plants have degraded Mutara rangelands in the North-eastern parts of Rwanda (Wronski et al. 2017). Tapping local knowledge in understanding past dynamics of spread of invasive species and their impacts would be a useful contribution in various management efforts (Finnegan, 1970).

5.3 Control of Invasive Species

Based on results findings, local efforts to control invasive species in villages around NCA still need promotion and support from different stakeholders. Starting from the Maasai pastoralists themselves, they need to change attitudes and learn new skills on land management. Traditionally, Maasai economy has been merely inclined on cattle (Wronski, et al. 2017), thus did not develop strong skills on agronomic practices like manipulation of plants communities in the landscapes. Mother Nature typically controls livelihood. It could be easier for the Maasai to walk couple of kilometers searching for good pasture rather than uprooting weeds to improve rangelands quality nearby their village. Thus, local government authorities like Ngorongoro District Council could provide rangelands management extension services to the Maasai in order to provide them appropriate skill for sustainable rangelands management. Supporting local livestock keepers has been advocate in National Livestock Policy of Tanzania (URT), 2006). In Ethiopia, local education on rangelands management has enabled local communities to improve livestock production levels and generate more household income within a short period of time (Abesha et al. 2000).

On the other hand, lack of land ownership among local pastoralists in the NCA (Ayubua et al. 2020) could be a limitation. There is a need of the NCA authority to identify appropriate measures that local people can adopt on controlling invasive plant species without affecting biodiversity in the NCA. Providing local pastoralists with simple tools like hand hoe or machete could be a promotion strategy that can be applied by the NCAA.

Fire has been widely used to control weed in landscapes (Corriher-Olson et al. 2020). During field visit at Endulen village, some farmers also attempted to use fire to control Makutian grass. Indeed, fire could be useful tool, but when not attended it could spread further and affected large part of ecosystem (Maponga, 2017). Hectares of grass land in natural ecosystems have been lost and several wildlife species killed following failure to manage wild fire (Maponga, 2017). Therefore, appropriate measures should be taken before local pastoralists have been allowed to use fire as a control measure of invasive plant species.

Concurrently, other conventional means of controlling weeds, like herbicides, should strictly not be allowed. Being chemical compounds, herbicides would kill various small wildlife species especially pollinators and decomposers. This will affect various ecological interactions within the ecosystem. Likewise, chemicals would infiltrate to nearby water bodies and cause eutrophication (Schütte et al. 2017).

5.4 Forage Quality in Range Lands

Results suggest that range land around NCA still hold capacity to provide nutritious forage to livestock. Higher desirability of grass compared to herb could be influenced by environmental factors, like rainfall regimes or soil properties, which might favor higher diversity and quality of grass species compared to herbs. While only 2% of grass was perceived undesirable, nearly 45% of herbs were not desirable as forage for livestock. Likewise, most of grass species from all three villages indicated suitability as edible forage. On the other hand, more than half of observed herbs were not perceived as edible forage.

However, there is a need of combining local indicators of forage quality and field measurements of forage nutrition status. Local indicators are highly appreciated, yet its interpretation would vary from one villager to another (Quinn et al. 2003). The limitation would worsen is the future if effort to pass local knowledge to younger generation would not be emphasized. Studies have indicated scientific indicators of good forage quality, protein, energy, vitamins and minerals decline as plants mature (Niu et al. 2016).

In contrary, poor indicators of forage quality like lignin and fiber content increase with plant age (Ball et al. 2001). Therefore, monitoring age of rangelands would be one of quick indicators that both pastoralists and research could use on monitoring rangelands quality.

Nevertheless, there are other confounding factors that influence variation of forage quality regardless of age factor. Soil physical or chemical properties would influence spatial variation of forage quality (Silveira and Kohmann, 2020) which is equally responded by trends of animal products. For example, higher milk production demand high supply of protein rich and higher moisture content forages. This implies that pastoralists should have a basic knowledge about various abiotic condition of the landscape to enable their decision on how to distribute livestock depending on what product they need to improve.

To sustain rangelands production capacity and income generated from livestock, there is a need of assisting pastoralists to develop a guideline for quality monitoring. Indeed, frequent monitoring of forage quality in the landscape could unpractical due to resource constraints. Therefore, researchers should work parallel with pastoralists to identify chemical parameters that fits well with indigenous indicators. A protocol would be established and train pastoralists to apply citizen science (Cohn, 2008) for monitoring dynamics observed in their own land.

5.5 Diversity and Abundance of Forage Species

Based on computed values of Shanon diversity index (*H´*), all three villages are characterized with higher diversity of grass species. According to Barbour et al. (1987), Shanon's Index value of >2 has been assigned as medium to high diversity. The higher diversity index in this location suggest that grazing practices leave the soil open and allow condition for emergence of new species or re-growth of suppressed species.

In contrary, herb species indicated higher diversity (*H´*> 2) only in Endulen village while Kayapus and Olbalbal indicated low species diversity (*H´*< 2). Low diversity of herbs in the last two villages suggests that few species have dominated others. It is suspected that, rangelands around Endulen would provide be characterized with poor provision of feed to livestock in case the dominant forage is less palatable to livestock.

5.6 Summary

This chapter has provided a detailed assessment on the local knowledge of pastoralists about the threats of invasive plant, and community preparedness on controlling these harmful plants. Additionally, it has assessed forage derisability, and the diversity of the rangelands plants in order to explain how rangeland quality varies at spatial scales.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This section provides a summary of the study findings and explain whether the aim of this study has been achieved or not. Additionally, it provides opinions about the importance of this work in a larger context.

6.2 Summary of Major Findings

The majority of villagers perceive IPS not nutritious forage to livestock, but have some medicinal value. IPS are known by pastoralists for many years, but its rapid expansion has been realized in recent years. Milk yield and loss of weight were perceived as serious problem of IPS compared to human infections. Livestock movement were perceived as the major cause of spreading IPS compared to change climatic condition and anthropogenic activities. Overall control of IPS is poor, however uprooting has indicated promising results followed by burning. Grass species indicated a wider desirability as livestock forage compared to herb species. Grass species indicated higher diversity and abundance compared to herbs species across all villages.

6.3 Conclusion

Based on the results obtained and discussions followed, the following main conclusion can be drawn. Given the fact that the majority of pastoralists indicated good knowledge about the effects of IPS to rangelands quality, less efforts from Government or NGOs is needed to raise local awareness about the negative impacts of

IPS to livelihood. Also, local participation in eradication of IPS could be more influenced by livestock economy rather than human health concerns.

Sources of spreading IPS are diverse and their expansion affect livestock, wild animals and humans. Therefore, they demand management approaches that involve voices and actions of local pastoralists, wildlife managers, social workers and policy makers. Despite increasing number of invasive herb species, high palatable grass species are still abundant in the rangelands at NCA. To avoid unforeseen future of rangelands' quality, more effective mitigation measures or suppressing IPS are needed in order to sustain the carrying capacity of rangelands.

6.4 Policy Recommendations

Education about the spread of invasive species and their effects should be mainstreamed in schools and extension training. This will help to broaden the knowledge about IPS across different members of community and shaping their perceptions towards common directions. In order to speed-up the control of IPS, suggested mitigation measures should fit well with local cultures, environmental safety and complement with daily economic activities of pastoralists. Where herbaceous invasive species has over-compete palatable grass species, deliberate efforts including hand planting of selected species is recommended.

6.5 Recommendations for Further Studies

The following studies are recommended in relation to this study;

(i) To determine whether the number or type of livestock kept by pastoralists correlate with abundance and distribution of invasive species.

(ii) To determine whether the impacts of invasive species to pastoral livelihood differ among individuals of different gender, age and education level across villages.

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APPENDICES

Appendix 1: Grass diversity and species abundance across study villages

Village	Species	n	(n/N=Pi)	P1^2	lnPi	PilnPi
Olbalbal	*Aristidakenyensis*	3	0.1071	0.0115	-2.23359	-0.2393
Olbalbal	*Chloris gayana*	1	0.0357	0.0013	-3.33220	-0.1190
Olbalbal	*Chloris pycnothrix*	2	0.0714	0.0051	-2.63906	-0.1885
Olbalbal	*Cynodondactylon*	3	0.1071	0.0115	-2.23359	-0.2393
Olbalbal	*Dactylocteniumaegytium*	3	0.1071	0.0115	-2.23359	-0.2393
Olbalbal	*Digitariascalarum*	1	0.0357	0.0013	-3.33220	-0.1190
Olbalbal	*Eragrostissuperba*	2	0.0714	0.0051	-2.63906	-0.1885
Olbalbal	*Microcloakunthii*	2	0.0714	0.0051	-2.63906	-0.1885
Olbalbal	*Penissetummezianum*	1	0.0357	0.0013	-3.33220	-0.1190
Olbalbal	*Sporobolusioclados*	10	0.3571	0.1276	-1.02962	-0.3677
Total	**10**	**28**				**-2.0082**

Village	Species	n	(n/N=Pi)	P1^2	lnPi	PilnPi
Kayapusi	*Chloris pycnothrix*	6	0.21424	0.0459	-1.5404	-0.3301
Kayapusi	*Digitariamacroblephara*	3	0.10717	0.0114	-2.2335	-0.2393
Kayapusi	*Cynodondactylon*	9	0.10717	0.0114	-2.2335	-0.2393
Kayapusi	*Eragrostisciliianensis*	4	0.1428	0.0204	-1.9459	-0.2779
Kayapusi	*Eragrostissuperba*	12	0.4285	0.1836	-0.8475	-0.3631
Kayapusi	*Eragrostistenuifolia*	5	0.1785	0.0318	-1.7227	-0.3076
Kayapusi	*Penissetummezianum*	2	0.0714	0.0051	-2.6390	-0.1885
Kayapusi	*Sporobolusioclados*	13	0.4642	0.2155	-0.7672	-0.3562
Kayapusi	*Sporobolusstapfianus*	6	0.2142	0.0459	-1.5404	-0.3301
Total	**9**	**60**				**-2.9624**

Village	Species	n	Pi	P1^2	lnPi	PilnPi
Enduleni	*Cynodondactylon*	2	0.0714	0.0051	-2.6390	-0.1885
Enduleni	*Cyperusrotundus*	3	0.1071	0.0114	-2.2335	-0.2393
Enduleni	*Digitariascalarum*	12	0.4285	0.1836	-0.8472	-0.3631
Enduleni	*Diheteropogonamplectens*	2	0.0714	0.0051	-2.6390	-0.1885
Enduleni	*Ehrhartaramosa*	1	0.0357	0.0012	-3.3322	-0.1190
Enduleni	*Eleusinejaegeri*	3	0.1071	0.0114	-2.2335	-0.2393
Enduleni	*Eleusine multiflora*	1	0.0357	0.0012	-3.3325	-0.1190
Enduleni	*Eragrostistenuifolia*	2	0.0714	0.0051	-2.6390	-0.1885
Enduleni	*Pennisetumclandestinum*	3	0.1071	0.0114	-2.2335	-0.2393
Enduleni	*Setariapumila*	1	0.0357	0.0012	-3.3322	-0.1190
Enduleni	*Sporoboluspyramidalis*	2	0.0714	0.0051	-2.6390	-0.1885
Enduleni	*Sporobolusstapfianus*	1	0.0357	0.0012	-3.3322	-0.1190
Enduleni	*Themedatriandra*	1	0.0357	0.0012	-3.3322	-0.1190
Enduleni	*Pennisetumschimperi*	2	0.0714	0.0051	-2.6390	-0.1885
Total	**14**	**36**				**-2.6186**

Appendix 2: Herbs diversity and species abundance across study villages

Village	Species	n	Pi	P1^2	lnPi	PilnPi
Olbalbal	*Acacia tortilis*	1	0.0769	0.0059	-2.5649	-0.1973
Olbalbal	*Asparagus africanus*	1	0.0769	0.0059	-2.5649	-0.1973
Olbalbal	*Blepharismaderaspatensis*	1	0.0769	0.0059	-2.5649	-0.1973
Olbalbal	*Commiphoratrothae*	1	0.0769	0.0059	-2.5649	-0.1973
Olbalbal	*Gutenbergiacordifolia*	1	0.0769	0.0059	-2.5649	-0.1973
Olbalbal	*Indigoferavolkensii*	2	0.1538	0.0236	-1.8718	-0.2879
Olbalbal	*Sphaeranthuscyanthuloides*	3	0.2307	0.0532	-1.4663	-0.3383
Olbalbal	*Tephrosiapumila*	3	0.2307	0.0532	-1.4663	-0.3383
Total	**8**	**13**				**-1.9513**

Village	Species	n	Pi	P1^2	lnPi	PilnPi
Endulen	*Acacia tortilis*	1	0.0769	0.0059	-2.5649	-0.1973
Endulen	*Achyranthes aspera*	1	0.0769	0.0059	-2.5649	-0.1973
Endulen	*Alternanthera pungens*	2	0.1538	0.0236	-1.8718	-0.2879
Endulen	*Amaranthus hybridus*	1	0.0769	0.0059	-2.5649	-0.1973
Endulen	*Bebbiajuncea*	1	0.0769	0.0059	-2.5649	-0.1973
Endulen	*Blepharismaderaspatensis*	2	0.1538	0.0236	-1.8718	-0.2879
Endulen	*Helichrysumforskahlii*	1	0.0769	0.0059	-2.5649	-0.1973
Endulen	*Heliotropiumsteudneri*	8	0.6153	0.3786	-0.4855	-0.2987
Endulen	*Justiciabetonica*	1	0.0769	0.0059	-2.5649	-0.1973
Endulen	*Tribulusterrestris*	1	0.0769	0.0059	-2.5649	-0.1973
Endulen	*Justiciamatanensis*	1	0.0769	0.0059	-2.5649	-0.1973
Endulen	*Enicostemaaxillare*	3	0.2307	0.0532	-1.4663	-0.3383
Enduleni	*Euphorbia hirta*	3	0.2307	0.0532	-1.4663	-0.3383
Total	**13**	**26**				**-3.1299**

Village	Species	n	Pi	P1^2	lnPi	PilnPi
Kayapusi	*Euphorbia hirta*	4	0.2105	0.0443	-1.5581	-0.3280
Kayapusi	*Launaeacornuta*	3	0.1578	0.0249	-1.8458	-0.2914
Kayapusi	*Medicago laciniata*	3	0.15789	0.0249	-1.8458	-0.2914
Kayapusi	*Oxalis lativam*	4	0.21052	0.0444	-1.5581	-0.3280
Kayapusi	*Sesuviumportulacastrum*	2	0.10526	0.0110	-2.2512	-0.2369
Kayapusi	*Trifolium rueppellianum*	3	0.15789	0.0249	-1.8458	-0.2914
Total	**6**	**19**				**-1.7674**

Appendix 3: House Hold Questionairres

A: GENERAL INFORMATION

A1. Date of interview …………………………………………….………

A2. Name of enumerator…………………………………………….………

A3. Name of respondent…………………….…………….…….….……

A4. Name of division……………..…………….………….………..………

A5. Name of village……………..……..………………….…..…….

B: BACKGROUND INFORMATION ON HOUSEHOLD HEAD

B1. Sex of respondent [ ]

01 = male

02 = Female

B2. Age of respondent in years [ ]

01 = 18 - 25

02 = 26 - 35

03 = 36 - 45

04 = 45 - 55

05 = above 55

B4. Education level? [ ]

01 = did not attend school

02 = Primary school

03 = Secondary school

04 = Tertiary education

05 = other; specify...

C. LOCAL PERCEPTIONS ABOUT INVASIVE SPECIES

C1. How do you perceive invasive plants [ ]

01 = harmful to animals

02 = not harmful

03 = beneficial to animals

04 = no idea

C2. Since when IS have been a problem in rangelands outside/inside NCAA [ ]

01 = Last 5 years

02 = 5-10 years

03 = 10-20 years

04 = above 20 years

C3. What could be the causes of IS invasion in this area [ ]

Answer..

....

....

....

....

C4. How IS affect game rangers activities?

Answers..

....

....

....

D. MANAGEMENT OF INVASIVE SPECIES

D1. How do you control invasive plants in this village [ ]

01 = burning

02 = slashing

03 = uprooting

04 = chemicals

05 = Nothing

D2. What strategies have been adapted to avoid impacts of IS to wild animals [ ]

Answer...

....

....

....

D3. Is this problem of IS recurrent (on and off)? [ ]

01 = Yes

02 = No

D4. If yes, how previous invasions of IS were controlled? [ ]

Answer...

....

....

....

....

E: RESPONSE OF WILD ANIMALS TO INVASIVE SPECIES

E1. How animals respond to t invasive species during grazing? (Circle correct answer)

		Behavior response									
	Species	**Itching**		**Avoiding**		**vomit**		**Refuge from predators**		**turn aggressive**	
1		yes	no	yes	no	yes	no	yes	no	yes	no
2		yes	no	yes	no	yes	no	yes	no	yes	no
3		yes	no	yes	no	yes	no	yes	no	yes	no
4		yes	no	yes	no	yes	no	yes	no	yes	no
5		yes	no	yes	no	yes	no	yes	no	yes	no

E2. How have your livestock affected when graze invasive species

		Physiological response											
	Types of Livestock	**Low milk yield**		**Lose weight**		**Stunted growth (Calves)**		**Infertility**		**Diarrhea**		**Dizziness**	
1	Cattle	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no
2	Sheep	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no
3	Goat	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no
4	Donkey	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no

E1. Which livestock type(s) are more vulnerable to IS? [ ]

01 = Cattle

02 = Goat

03 = Sheep

04= Donkey

E2. Which part of IS plants are mostly avoided by livestock? [ ]

01 = Flower

02 = Leaves

03 = Shoot

04= Roots

E3. Which age of IS plants is mostly dangerous to livestock? [ ]

01 = young

02 = matured

03 = both

Appendix 4: Research Clearance Letter

THE OPEN UNIVERSITY OF TANZANIA

DIRECTORATE OF POSTGRADUATE STUDIES

P.O. Box 23409
Dar es Salaam, Tanzania
http://www.openuniversity.ac.tz

Tel: 255-22-2668992/2668445
ext.2101
Fax: 255-22-2668759
E-mail: dpgs@out.ac.tz

REF: PG201702245

14st July 2020

Conservation Commissioner,
Ngorongoro Conservation Area,
P. O. Box 1
ARUSHA.

RE: RESEARCH CLEARANCE

The Open University of Tanzania was established by an Act of Parliament No. 17 of 1992, which became operational on the 1st March 1993 by public notice No.55 in the official Gazette. The Act was however replaced by the Open University of Tanzania Charter of 2005, which became operational on 1st January 2007. In line with the Charter, the Open University mission is to generate and apply knowledge through research.

To facilitate and to simplify research process therefore, the act empowers the Vice Chancellor of the Open University of Tanzania to issue research clearance, on behalf of the Government of Tanzania and Tanzania Commission for Science and Technology, to both its staff and students who are doing research in Tanzania. With this brief background, the purpose of this letter is to introduce to you **Mr. Dismas Cyril Macha, Reg. No: PG201702245** pursuing **Master Arts in Natural Resources Assessment and Management.** We here by grant this clearance to conduct a research titled ***"Socio-Economic Impacts of Invasive Alien Plant Species on Pastoralism: A Case Study of Ngorongoro Conservation Area"***. He will collect his data in your office between July to August 2020.

In case you need any further information, kindly do not hesitate to contact the Deputy Vice Chancellor (Academic) of the Open University of Tanzania, P.O. Box 23409, Dar es Salaam. Tel: 022-2-2668820.We lastly, thank you in advance for your assumed cooperation and facilitation of this research academic activity.

Yours Sincerely,

Prof. Hossea Rwegoshora
For: VICE CHANCELLOR
THE OPEN UNIVERSITY OF TANZANIA