LOCAL AND LANDSCAPE LEVEL IMPACTS OF ENCLOSURE AND PATTERNS USED BY PASTORALIST IN SHAPING PLANT DIVERSITY OF RANGELANDS, EASTERN ETHIOPIA

PhD Dissertation

By

Buli Yohannis Tasisa

Addis Ababa University
Graduate Programmes
Faculty of Natural & Computational Sciences
Department of Plant Biology and Biodiversity Management

Date: September 23, 2018

Addis Ababa, Ethiopia

LOCAL AND LANDSCAPE LEVEL IMPACTS OF ENCLOSURE AND PATTERNS USED BY PASTORALIST IN SHAPING PLANT DIVERSITY OF RANGELANDS, EASTERN ETHIOPIA

A dissertation submitted to the Department of Plant Biology and Biodiversity Management of Addis Ababa University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Plant Biology and Biodiversity Management

PhD Dissertation

By

Buli Yohannis Tasisa

Date: September 23, 2018

Addis Ababa, Ethiopia

Addis Ababa University

Graduate Programme

Faculty of Natural & Computational Sciences

Department of Plant Biology and Biodiversity Management

As members of the Examining Board of the final PhD open defense, we certify that we have read and evaluated the Dissertation prepared by Buli Yohannis titled: Local and landscape level impacts of enclosure and patterns used by pastoralist in shaping plant diversity of rangelands, eastern Ethiopia and recommend that it be accepted as fulfilling the dissertation requirement for the Doctor of Philosophy in Rangeland Ecology.

Insert Name ________________________________

Chairman Signature Date

Name ________________________________

Internal Examiner Signature Date

Name ________________ ________________

External Examiner Signature Date

Prof. Sileshi Nemomissa ________________ ________________

Advisor Signature Date

Dr. Tamrat Bekele ________________ ________________

Advisor Signature Date

ABSTRACT

The study was done in the rangelands of Ethiopian Somali region in Shinile Woreda. The study was aimed to understand the impact of enclosure at local and landscape level and patterns used by pastoral community in shaping plant diversity of rangelands with the following specific objectives: to identify the effects of patch enclosure and *Acacia* shade on herbaceous species richness and soil properties; to evaluates the quality of seed and maternal body size of selected plant species within inside enclosure compared with nearby outside; to determine the impact of enclosure on plant diversity and richness at local and regional species pool and to assess the perception and indigenous knowledge of pastoralists in rangeland management. Four enclosures and four open grazing areas were considered for this study. The vegetation and soil surveys, seed collection and measurement of parental body size of selected species were conducted during wet seasons, i.e., from June to September of 2016.Vegetation data were sampled from 300 quadrates (1mx1m) for herbaceous, 300 quadrates (5mx5m) for shrubs and 60 quadrates (20mx20m) for woody species. Herbaceous and soil data were also sampled from 40 quadrates. Plants were collected following standard herbarium technique. All sampled plants were identified at National Herbarium of Addis Ababa University. Soil samples were analyzed for pH, EC, %OC, %OM, available P and exchangeable K at Soil, Plant and Water Analysis Laboratory of Harames University. Six grass species were selected for detailed studies such as seed number, seed weight, height and tiller number. Statistical analyses were carried out by using R and SPSS software. Correlation coefficients and regression analyses were verified. One-way ANOVA and Turkey HSD multiple comparisons were used to perform multiple comparisons. A total of 39 herbaceous and 36 woody species were identified from the study area. Grass species richness was significantly high inside enclosure ($P=0.000$). Herbaceous species richness were significantly high under *Acacia* shade ($P=0.001$). Enclosure has no effect on soil EC, %OC, %OM, P and K ($P>0.05$). However, only soil pH has significantly increased at inside of enclosure ($P=0.000$). Plant height has significantly increased inside enclosure for all selected species except for *Tragus berteronianus*. Tiller number has significantly increased inside enclosure for all species ($P<0.023$) except for *Eragrostis cilianensis*. Enclosure also significantly improves seed number and weight of all selected grass species ($P=0.000$). *Acacia* shade significantly improves only plant height for all selected grass species. The result of Shannon-Weiner diversity index showed that local species pool were lower in plant diversity than both ecological and regional species pool. Unlikely, the species richness within local species pool were higher than both ecological and regional species pool. Shinile Woreda pastoralists have an in-depth knowledge and experience regarding the changes that the rangeland ecosystem has undergone. This knowledge and experience is believed to have profound importance for possible integration of scientific principles and practices for future sound rangeland management system in the region.

Key words: ***Acacia*** **canopy, enclosure, herbaceous species, indigenous knowledge, pastoralist, rangeland, seed quality, soil chemistry, woody species**

STATEMENT OF AUTHOR

First, I declare that this dissertation is my work and that all sources of material used for this thesis have been duly acknowledged. This dissertation has been submitted in partial fulfillment of the requirements for a PhD degree at Addis Ababa University, Graduate programmed, and Department of Plant Biology Biodiversity Management and is deposited at the University/College library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however permission must be obtained from the author.

Name: Bali Johannes Tessa Signature: ______________

Graduate Programmed, Addis Ababa University

Date of Submission: September 23, 2018

ACKNOWLEDGEMENTS

Above all, I thank and glorify the Almighty God in the name of our Lord Jesus Christ for giving me Eternal life. He providing me abundantly with everything I needed throughout my studies.

First and foremost I offer my heartfelt thanks and deepest appreciation to my Advisors Professor Silesia Nemomissa and Dr. Tamrat Bekele for their kind supervision, cheering guidance, sympathetic attitude, motivation and encouragement.

I sincerely acknowledge Addis Ababa and Jigjiga University for providing grant for this research. Once more again I thank Jigjiga University, they provide me car during all time I have been in field for data collection. I would like to express my sincere thanks and appreciation to National Herbarium of Ethiopia in Addis Ababa University and Soil, Plant and Water analysis laboratory of Haramaya University, for their institutional and facility support.

Due acknowledgement also goes to the elders, leaders, herders and all household of Shinile Woreda for their devotion and participation during the survey by giving me all information we need through questionaries' and interview by scarifying their time. Once more, outstanding acknowledgement also goes to the elders of Somali pastoralists for their contribution during the survey by giving me vernacular name of each plant and allows me to work inside their enclosure for plant and soil sample collection.

I am also grateful to my coworker, all data collector and drivers for their support during all activities I had with them. I could not have completed this work without their encouragement, support and brotherhood.

I also extend my heartfelt respect and deepest love to my wife Bikiltu Shewakena and my beloved family mainly my father Yohannis Tasisa, my mother Birke Geneti and all my brothers and sisters for their prayer, encouragement and support throughout my studies.

DEDICATION

This thesis is dedicated to all the pastoral community of Ethiopia, whom managed their environment to maintain productivity of the arid rangelands through their indigenous knowledge.

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
CSA	Central Statistical Authority
DF	The Development Fund
EARO	Ethiopian Agricultural Research Organization
FGD	Focal Group Discustion
EC	Electron conductivity
FAO	Food and Agricultural Organization
GPS	Global Positioning System
GDP	Gross Domestic Product
IEUA	Inside Enclosure Under *Acacia*
IEWA	Inside Enclosure Without *Acacia*
IIRR	International Institute of Rural Reconstruction
K	Potassium
Km	Kilometer
masl.	Meter at sea level
N	North
NGO	Non-governmental organization
NHEFF	National Herbarium of Flora and Faunas of Ethiopia
OC	Organic Carbon
OEUA	Outside Enclosure Without *Acacia*
OEWA	Outside Enclosure Without *Acacia*
OM	Organic matter
P	Phosphorous
PCDP	Pastoral Community Development Program
PFE	Pastoralist Forum Ethiopia

pH	Power of hydrogen
ppm	Parts per million
RPPACC	Regional Program of Plan to Adapt to Climate Change
SCBD	Secretariat of the Convention on Biological Diversity
SD	Standard deviation
SoRPARI	Somali Region Pastoral and Agro-Pastoral Research Institute
SPSS	Statistical Package for Social Sciences
SERP	Southern Eastern Rangeland Development Project of Ethiopia
UNDP	United Nation Development Program
UNCED	United Nation Conference on Environment and Development
UNCCD	United Nations Convention to Combat Desertification

TABLE OF CONTENTS

1. INTRODUCTION

Rangelands occupy about 50 % of the world's land area (Friedel, *et al*., 2000). Nearly, half of the world rangeland area lies in the tropics and sub-tropics, between 23^{o}north and south of the equator (Alemayehu, 2006). In Africa, rangelands are the major sources of feed for animals and constitute about 65 % of the total land area which supports 59 % of all ruminant livestock (Friedel, *et al*., 2000). The nature of African rangeland including Eastern Africa is dominated by arid and semi-arid climate having low and unreliable rainfall, low soil fertility, high temperature and evapo-transpiration (Coppock, 1994).The rangelands of Ethiopia are mainly located within the arid and semi-arid agro-ecological zones below 1,500 masl (Coppock, 1994; Alemayehu, 2004) and cover about 62% (682,000 km^2) of total land area of the country (EARO, 2002). These areas support different types of livestock and they are the major browsing and grazing areas of the country.

The Ethiopian Somali region is mostly semi-desert and desert with high temperatures and low precipitation. Different arid and semi-arid rangeland vegetation types, such as grasslands, open bush grassland and closed bush land are found in the regional (SoRPARI, 2005). These rangelands are rich in botanical resources, but at present they are subjected to human and natural influences which reduce biodiversity (Gemedo-Dalle, *et al.*, 2006). Loss of plant cover, undesirable change in herbaceous species composition (e.g. annual grasses replacing perennials), soil erosion of various types associated with intensification of grazing and woody encroachment have been dominant features in the rangelands which could have different implications for pastoral productivity and rangelands potentials. Due to this reason, pastoral communities internalize the problems mainly through engagement in land use types that directly compete with their life. One of the resolutions they seek through is a traditional rangeland management activity that focuses mostly on natural forage of rangeland (Sandford, 1983). Proliferation of an enclosures may be cited as examples as the solution (Tache and Oba, 2010; Tache, 2010; Berhanu and Colman, 2007). Reserving a section of the communal rangeland through enclosure for later use has always been an integral part of pastoralist innovation in land use in the arid and semi-arid environments where pastoralist land use strategies are largely influenced by spatial and temporal resource variability.

The establishment of communal enclosures in area followed the critical drought in 1983 which led to massive livestock mortality (Alison and Solomon, 2011). Under ideal common property resource tenure, a decision to make an enclosure is made through consensus. Management of the enclosed pasture is a collective responsibility and utilization is for communal purpose. The main functions of making an enclosure are to rehabilitate degraded rangeland by enhancing recovery in place where soil degradation and overgrazing are common. Nowadays there are many type of enclosure. One is the communal enclosure where a group of villages reserve pasture on communal basis The communal pasture reserves, locally known as *seero*, provided a means for meeting the special need of pastoral community. The second type is the enclosures used by the community but introduced or supported by nongovernment organizations (NGOs). The third category is private enclosure which is not common like others (Talasan, 2009; Napier and Desta, 2011).

The importance of rangeland is far greater than rangeland managers generally appreciate as they are mostly concerned with only one of the function of rangelands; animal production. However, rangelands are also of great ecological importance, because rangeland vegetation type protect often fragile soil profiles, harness large amount of carbon dioxide, are a habitat for wild fauna and flora and acts watersheds for large river system (Friedel, *et al.,* 2000).Heady in (1999), indicated that rangeland improvement and maintenance are necessary for various benefits and ecological balance to determine sustainable, optimal grazing capacity and maximum profitability for livestock production which requires the knowledge of the biological, physical and socio-economical characteristics of the system. In the extensive communal low land grazing areas of Ethiopia, herbaceous and woody plants are the major feed source of livestock (Abule, *et al* 2005; Abule, *et al* 2007) which support more than 90% of the domestic ruminants (Alemayehu, 2004).

Despite providing crucial ecosystem services, rangeland areas are being degraded, particularly in the arid and semi-arid environments of Africa and Asia (Neely, *et al.*, 2009; Steinfeld, *et al.*, 2006). The causes of shrinking and degrading of rangelands are natural and manmade bases such as increase in human population, urbanization, crop encroachments, settlement and recurrent drought (Coppock, 1994; Beruk and Tafesse, 2000; Alemayehu, 2004).There are various factors affecting the utilization of rangeland resources, the socioeconomic, and the biological and physical factors are the case in point. The term rangeland degradation refers to both soil and vegetation and is generally defined as the reduction of the economic or biological productivity of lands (FAO, 2011). The degradation of rangeland bio-physical conditions such as vegetation cover, soil fertility, feed mass production and plant biodiversity has resulted in deteriorations of the range-livestock production systems and the pastoral livelihoods in the Ethiopian Somali region (Kassahun, *et al.,* 2008). The excessive shrinkage in rangelands and poor management practices applied to rangelands resulted in serious land degradation, reduced biodiversity, gradual decline in nutritive value and replacement by poorly palatable and drought tolerant species (Alemayhu, 2004; Abule, *et al* 2007). As a result, availability of feed is the major constraint in livestock production particularly in the arid and semi-arid areas of the country (Belaynesh, 2006). Currently, a significant number of grass, shrub and tree species of high feed, habitat and economic values for the livestock, wild animals and pastoralists of the Ethiopian Somali region, are at a risk of local extinction. Implementing rangeland conservation strategies can increase both the provisioning and regulation of services derived from rangelands, thereby improving pastoralists' livelihoods and long-term ecosystem health (Notenbaert, *et al.* 2012).

Substantial research and development works have been conducted in most of the arid and semi-arid rangelands of Ethiopia. For instance, various studies were conducted on the role of pastoralist in rangeland management, utilization practices,the perception, land degradations and rangeland vegetation responses to settlement; in southeast and eastern part of Ethiopia (Abate, *et al.*, 2010; Baars, and Said, 2002), Southern Oromia (Tache, 2013), Borana, (Oba, 1998; Gemedo- Dalle, *et al*., 2006), Yabelo Woreda (Dika, 2016), Guji zone (Teshome, 2016), Chifra district of Afar Regional state, (Abdulatife and Ebro, 2015) and in Tigray (Solomon and Yayneshet, 2014).

However, in the Ethiopian Somali regional State in general and the Shinile Woreda areas in particular, research and development interventions have been insignificant (Gezu, 2011). Limited studies conducted in the region which were focused on rangeland resources and establishment of enclosure were; the impact of rangeland degradation on the pastoral production systems, livelihoods and perceptions of the Ethiopia Somali pastoralists (Kassahun, *et al.,* 2008); Characterization of rangeland resources and dynamics of the pastoral production systems (Amha, 2006);Changing pastoralism in the regional (Sugule and Walker, 1998); The impact of enclosures on access to rangelands (Talasan, 2009). Assessment of pastoralists' views on enclosures in Shinille and Dollo (Gezu, 2011) and range and forestry biophysical business process, establishment of area enclosures to rehabilitate and improve degraded rangelands (SoRPARI, 2011)**.** Clearly, there is lack of information on impacts of enclosure in plant composition (richness and diversity), quality of seed and maternal body size and soil nutrient status across study area that would contribute a lot regarding optimal utilization of the rangeland resources. Moreover, issues of enclosure on the protection of woody species, which are important for proper rangeland management, were also generally ignored in those limited studies.

Therefore, the objectives of this study was to understand the impact of enclosure at local and landscape level and patterns used by pastoral community in shaping plant diversity of rangelands with the following specific objectives. These are (1) to identify the impacts of patch enclosure and selected *Acacia* shade on herbaceous richness and soil properties, (2) to evaluates the quality of seed and maternal body size of selected plant species within inside enclosure compared with nearby outside, (3) to determine the impact of enclosure on plant diversity and richness at local and landscape species pool and (4) to assess the perception and indigenous knowledge of pastoralists in rangeland management.

2. LITERATURE REVIEW

2.1Overview of rangeland in World, Africa, Ethiopia

Rangeland ecosystems are among the earth's largest terrestrial ecosystems and are found in all continents of the world (Kreutzmann *et al.*, 2011; Lund, 2007; Fig. 1.1). The various definitions of rangelands that have been proposed can possibly be attributed to the huge variety of rangelands that cover diverse vegetation types (Sayre *et al.*, 2013; Lund, 2007). Rangeland, in broad sense, is land cover/use category that includes land on which the climax or potential plant cover is composed principally of native grasses, grass-like plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangelands (NRCS, 1997). Rangelands are the large areas between deserts and agricultural zones where rainfall is generally too low or unreliable for cropping and where livestock keeping is the most important source of income (Walker and Abel, 2002).

Global estimates of rangelands also vary widely and range from 18% to 80% (Lund, 2007; Mannetje 2002) of the earth's land surface. The estimates vary depending on the definition of rangelands and data sources. SRM (2006) provides estimates of the global extent of major rangeland vegetation types as follows: grassland 42%, shrubland 23% and woodland 12%, with the other vegetation types forming 23% of the earth's land surface. Similar estimates are cited in Suttie *et al.*, (2005), who give an estimated figure of 77% for the global extent of rangeland vegetation cover.

In Africa, rangelands are the major sources of feed for animals and constitute about 65 % of the total land area which supports 59 % of all ruminant livestock (Friedel *et al.*, 2000). The nature of African dry land including Eastern Africa is dominated by arid and semi-arid climate having low and unreliable rainfall, low soil fertility, high temperature and evapo-transpiration (Coppock, 1994). The rangelands of Ethiopia, which accounted 62% (682,000km^2) of the total area of the country, are mainly located within the arid and semi-arid agro-ecological regions below 1,500 masl. (EARO, 2002). In the rangelands of Ethiopia, pastoral and agro-pastoral production system represent the largest land use system of the agricultural sector and are based on mobile rangeland livestock production system (Amaha, 2002).

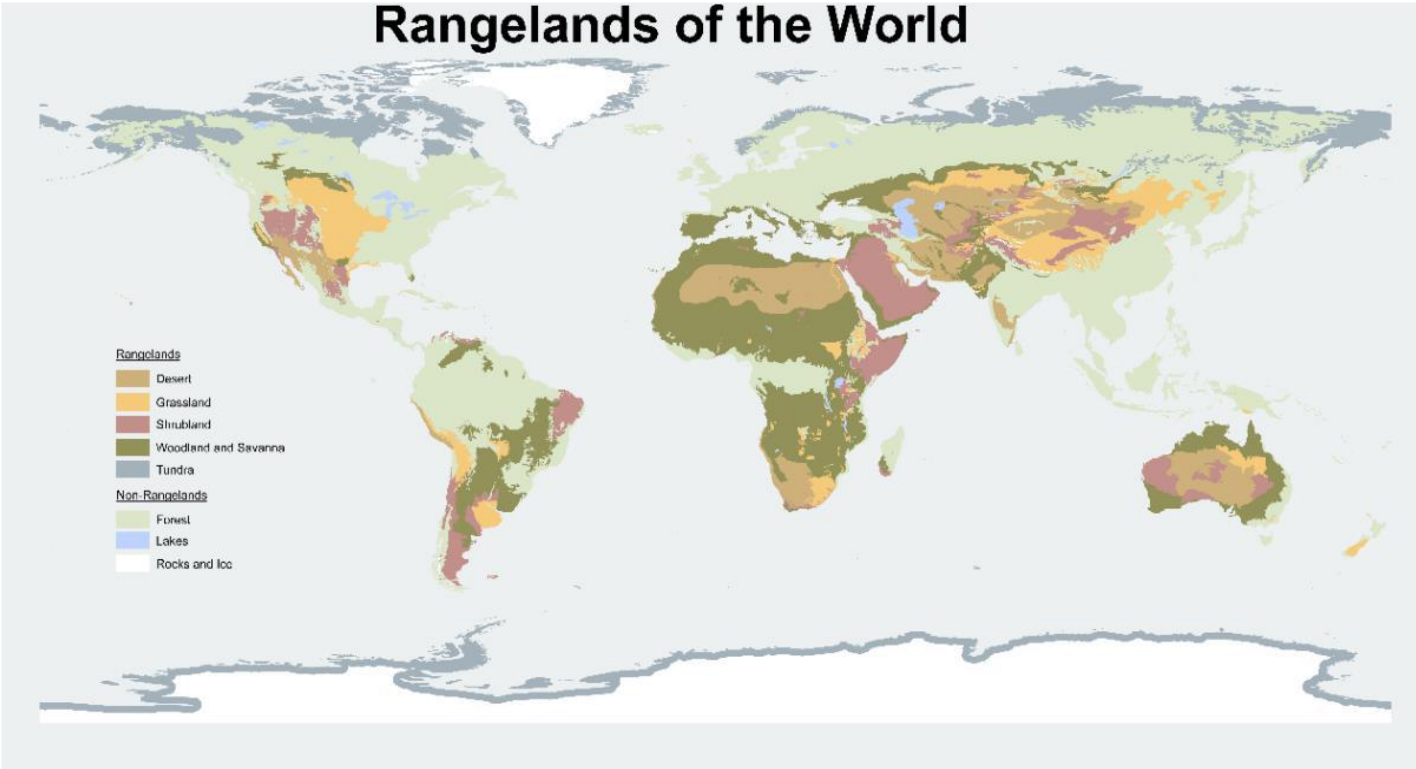


Figure 1: Rangelands of the world

Source: http://www.webpages.uidaho.edu/what-is-range/rangelands_map.htm

2.2. Feature and Importance of Rangelands

Rangelands are land producing native forage for animal consumption (Coppock, 1994). Most rangelands are at best only marginally suitable for arable cropping in most developing countries and rangelands are responsible for the major portion of the feed consumed by ruminants. Rangelands play an important role in the national economies of less developed countries in which a large number of the population depend on these native forage producing lands for livelihood (Alemayehu, 2004). Forage for livestock is the primary contribution to humans of rangelands in the world especially for developing countries. This is true for Africa and South America (Holechek, *et al*., 2005). However; many of these rangelands are presently undergoing extensive deterioration in developing countries including Ethiopia.

Sixty-five percent of global dry lands host rangelands, a base for livestock production that contributes to foods and livelihoods security of 800 million people (Mortimore, 2009). The arid or semi-arid areas are suited for extensive livestock production and cover nearly half of the

African continent (Cossins, 1983). Many of these areas are inhabited by pastoral people that depend on a rangeland resources and rural livelihood activities (Coppock, 1994; McPeak and Barett, 2001). Pastoralists occupy about 52% of the total area of Ethiopia (Markakis, 1993). Pastoralists in these areas experience frequent droughts, animal and human disease epidemics, and reduced mobility due to cropping, settlement, and protected areas (Coppock, 1994; Fratkin, 2003).

Rangelands, like other natural resources, provide essential ecosystem services for human welfare, both directly and indirectly (Costanza, *et al.*, 1997). The main recognized direct service provided by rangelands is their contribution as a source of feed and habitat for livestock and wildlife (Mannetje, 2002; Larbi, *et al.*, 2009, Sayre, *et al.*, 2013). Livestock production is found in approximately two thirds of rangelands worldwide, with about 1 billion people mainly depending on livestock for their livelihoods and about 70 percent of the rural poor households partially depending on livestock as a source of income (Neely, *et al.*, 2009). These ecosystems are of high value, particularly in developing countries, where they provide the main feed resource for traditional livestock production systems and are a main source of livelihood for millions of rural households (Mannetje, 2002). Africa's pastoralists have developed very resilient grazing systems that manage to maintain relatively high human populations on rangelands of low and highly variable productivity. They use a mixture of species (cattle, sheep, goats, camels) and traditional breeds mainly selected for adaptation to the harsh environment. Small ruminants with their higher reproductive rate play a key role in building up livestock populations after periodic droughts have led to destocked systems (FAO/ LEAD, 1995).

Rangelands are land producing native forage for animal consumption (Coppock, 1994). Most rangelands are at best only marginally suitable for arable cropping in most developing countries and rangelands are responsible for the major portion of the feed consumed by ruminants. Trees and shrubs are important sources of fodder for livestock in the tropics and dry environments and withstand harsh climatic conditions better than herbaceous species (Silanikove, *et al.*, 1996). They provide green forage for grazing animals throughout the year (evergreen species) or at specific critical periods of the year (deciduous species) (Kökten, *et al.*, 2012). In arid and semi-arid regions most perennial browse species are reported to maintain vegetative growth with fresh leaves and twigs hence with apparent maintenance of nutritive value throughout the dry season while grasses dry up and deteriorate both in quality and quantity (Tolera, *et al*., 1997; Hussain and Durrani, 2009; Cavalcante, *et al*., 2014). *Acacia* woodlands represent one of the most widespread vegetation types of dry lands in Africa (Traoré, *et al*., 2012). *Acacia* trees dominate in many parts of the arid and semi-arid areas of Sub-Saharan Africa, and have multiple uses (El-Beheiry, 2009). *Acacia hockii* is native to many dry areas in tropical Africa south of the Sahel, to eastern and southern Africa. *Acacia senegal* is a widespread leguminous tree (Raddad, 2006) distributed in the drier parts of tropical Africa (Wekesa, *et al*., 2009). *Acacia seyal* is widespread in the semi-arid zone of tropical Africa from Senegal eastwards to Somalia and the Red Sea and from the Nile valley south to Zambia (Fall, *et al*., 2009). *Acacia seyal* is widely distributed in the African savannas and considered as one of the most common trees on clay plains that flood during the rainy season (McAllan, 1993). Several species of *Acacia cochliacantha* have been recognized by grazers because of their feeding value during the drought (Olivers-Pérez, *et al*., 2013). It has been reported that the pods and leaves of *Acacia seyal* are nutritious and palatable to livestock (Abdalla, *et al*., 2014a). Additionally *Acacia nilotica* fruits *has high* Feedstuff potential and serve as nutritious plant for livestock in the drylands of Sudan Abdalla, *et al*., 2014b).

2.3. Rangeland biodiversity degradation

Rangeland degradation also has negative effects on biodiversity. Trends in economically useful plants over time have been on the decline with intensification of land use and the subsequent negative consequences on the ecological function of rangelands (Maitima, *et al*., 2009).The potential biodiversity of rangelands is only slightly less than that of forests, and that the low levels of diversity currently recorded in many of the world's rangelands is a result of human influence (Blench and Sommer, 1999). There is evidence that the biodiversity of the world's rangelands is declining alarmingly, through mismanagement, inappropriate habitat conversion and, more recently, due to climate change. The Millennium Assessment estimated that climate change will be the main driver of biodiversity loss by the end of the century (IIED/WWF, 2007). Biodiversity can be described as the diversity of life on Earth. Simply put, biodiversity is the variety of all living things, the places they inhabit, and the interaction between the two. Interactions between the components of biodiversity make the Earth inhabitable for all species, including humans. Biodiversity is directly responsible for around 40% of the world's economy, particularly in sectors such as pastoralism, agriculture and forestry, and for ecosystem services such as clean water and soil fertility.

Biodiversity loss in rangelands is directly affected by overgrazing typically livestock returning to re-graze plants before adequate recovery and by land degradation which causes changes in species composition and intra-species competition (Blench and Sommer, 1999). This is exemplified by bush encroachment and loss of less-resilient plant species and loss of habitat and associated species that provide support functions, such as predation and pollination. The International Union for Conservation of Nature has identified livestock management as one of the threats to as many as 1700 endangered species (FAO/LEAD, 2006). Land conversion is the other main cause of biodiversity loss. For example, of the 13million ha of forest lost annually (FAO, 2005), land cleared for livestock accounts for some 1.5 million ha per year (De Haan, *et al.*, 2001), resulting in severe loss of habitat and species. In other way the pastoralists asserted that encroachment of woody plants become the major challenge to their livelihoods through decreasing production of grazing land; which ultimately made them food insecure (Abebe, *et al.*,2012)

Biodiversity loss in rangelands has significant implications in terms of vulnerability to climate change and the food security of those directly dependent on rangelands as well as those living outside rangelands but who depend on livestock for protein (Blench and Sommer, 1999). Studies on degraded agro-ecosystems in Sudan have shown that maintaining and promoting the use of biodiversity in grasslands can increase soil C sequestration, while sustaining pastoral and agricultural production (Olsson and Ardo, 2002). Innovative approaches to achieving both livelihood and biodiversity goals include: grazing for habitat management, cooperative corridors, adaptations of traditional pastoralism, co-management of livestock and wildlife, disease and predator management, and game ranching (Neely and Hatfield, 2007).

2.4. The impact of herbivores and human in rangeland degradation

Herbivores grazing and human interference can reduce growth and survival of plants community at a particular site. Anthropogenic factors and overgrazing can aggravate the loss of native resources and vegetation and jeopardize the region’s unique biodiversity. For instance, various study revealed grazing lands at present are shrinking and degrading due to natural and manmade causes such as overgrazing, recurrent drought, increase in human population, urbanization and crop encroachments, settlement and conflicts (Coppock, 1994; Beruk and Tafesse, 2000; Alemayehu, 2004).Recent increases in human and livestock populations and decreases in the availability of grazing lands are also putting the rangeland resource under increased pressure (Coppock, 1994; Helland, 1997).

Further, many habitants of arid and semi-arid areas in Africa including Ethiopia derive most of their incomes from extensive livestock production totally reliant on rangeland vegetation (Kamara, *et al.*, 2004), and may be hugely affected should these resources be allowed to degrade (Leakey, 2002). Thus, in order to effectively manage the biodiversity of local and regional vegetation in rangeland and ensure sustainability for the future generation, it is critical to gain a better understanding of how local communities adapt to changes in their environment (Berkes, *et al.*, 1998; Bolling and Schulte, 1999; Stringer, *et al.*, 2007). In arid Ethiopian landscapes, population growth, intensification livestock population, increasing demand for natural resources, and environmental degradation create environmental stresses that have considerable socio-economic and ecological consequences (Bolling andSchulte, 1999; Mouat, *et al.*, 1997; Sinclair and Fryxell, 1985; UNCCD, 2000; UNCED, 1992).

These pressures have led to inappropriate systems of land use that can greatly contribute to the loss of vegetation (Angassa and Oba, 2008). According to Angassa and Oba, (2008), land use changes linked to bush invasion in dryland ecosystems threaten both indigenous plants and animals and exacerbates soil erosion, with far-reaching implications for local communities. Oba, *et al.* (2000) has reported that the grazing effectiveness of dryland ecosystems is completely eliminated if bush encroachment exceeds 90% of the vegetation cover. Generally, dryland ecosystems are subject to increasing land use changes as human need for food and natural resources rise, which eventually contributes to climate change (Grover, *et al.*, 2011).

Recent increases in human and livestock populations and decreases in the availability of grazing lands are putting the rangeland resource under increased pressure (Coppock, 1994; Helland, 1997).

Majority of the animals in arid and semiarid are raised on rangelands where feed resources are mostly natural grazing grasses, forbs with some browse shrubs and trees (Abusuwar andAhmad, 2010). The productivity of range animals is directly related to the amount and nutritive quality of forage available to grazing animals (Hussain and Durrani, 2009). Range resources are heterogeneous and dispersed, tied with seasonal rainfall patterns, differing through time and characterized by overall erratic climatic patterns (Nori, *et al*., 2008).

The productive value of a pasture is mostly determined by the amount consumed by an animal and contribution of the required nutrient for maintenance and production (Asaadi and Yazdi, 2011). It is well known that forages have an important role in ruminant animal production in terms of providing energy, protein and minerals (Kamlak, 2010). Reports indicated that in most highlands of Ethiopia more than 90% of the feed for ruminant animals are derived from native forages, where the nutritional status of the latter may be affected by various factors (Tolera, *et al*., 1997). The availability and quality of the different browse and grass species is believed to vary from season to season due to marked seasonality in rainfall distribution that affects the growth and development of the plant species, particularly that of the grasses and other herbaceous species (Abebe, *et al*., 2012). In East African rangelands, grazers are greatly influenced by the nutritional dynamics of forage, especially during the dry season (Teka, *et al*., 2012). In Ethiopia, despite having good number of farm animals, productivity is quite low. Among other factors, poor nutrition is a major constraint limiting livestock performance. Consequently, this leads to high mortality amongst livestock, longer calving intervals, and substantial weight loss, particularly during dry season that usually extends from December to May in most of central Ethiopia (EARO, 2000; Belete, *et al*., 2012). The deficiency of nutrients leads to under nourishment, low productivity and predisposes the livestock to diseases and parasite infections, and breeding problems (Rahim, *et al*., 2008; Rasool, *et al*., 2013). Therefore, it is important to monitor the nutrient contents and its dynamics over time and space so as to determine the rangeland's carrying capacity and adjust stocking rates; decide proper time of utilizing the range vegetation, and prediction of any malnutrition and related health hazards.

2.5. Rangeland soil

Soil is the most important component of rangeland ecosystems. It has an interdisciplinary nature and is associated with biodiversity, biogeochemical cycling, hydrology, human health and social sciences (Brevik, *et al.,* 2015). The survival and physical condition of plants depend on the regular supply of mineral nutrients from the soil (Badshah, *et al*., 2012). Minerals are essential not only for the normal growth and development of plants but also for the growth, maintenance and productivity of grazing livestock in rangelands (Hussain and Durrani, 2008). Unfortunately, rangelands have undergone rapid alteration as a result of factors such as overgrazing, deforestation, woody-plant encroachment, and invasion by non-native plant species (Wilcox and Thurow, 2006). Each of these factors has led to a reduction in the quantity and/or nutritional quality of the vegetation available for grazing; this is known as "range- land degradation" (Li, *et al.,* 2013). Insufficient plant growth and reproductive problems can directly be related to mineral deficiencies caused by low mineral concentration in soils (Tiffany, *et al*., 2000). Soil is a heterogeneous, diverse and dynamic system (Kavianpoor, *et al*., 2012). The soil property associations and their physical, hydrological, and biological characteristics that produce distinctive kinds and amounts of vegetation are an essential component of a given rangeland ecosystem (Pyke, *et al*., 2002). Soils with good physical and chemical characteristics are essential in maintaining productivity in terrestrial ecosystems and driving processes that maintain environmental quality (Moussa, *et al*., 2008).

It is believed that livestock grazing is associated with rangeland degradation. Grazing is the most important factor affecting vegetation and soil in all rangelands of the world, having a critical impact on rangeland biodiversity and species composition (Gamoun, 2014; Sharafatmandrad, *et al.,* 2014; Angassa, 2014; Bahareh, *et al.,* 2016) and soil erosion (Mekuria and Aynekulu, 2013). Relationship between plants evening and soil properties in the rangeland, showed increase the content of organic matter and potassium which caused increased ecologic habitats in the soil (Jamil Amanollahi, *et al.,* 2011). This led to the growth of rare species of plants. Because these rare species need high level of soil fertility and consequently causing a decrease in shade evening.

Rangelands are essential to the subsistence of pastoralists and agro-pastoralists, which usually constitute the most vulnerable groups in this land-use system. Rangelands are estimated to store up to 30 percent of the world's soil carbon in addition to the substantial amount of above-ground carbon stored in trees, bushes, shrubs and grasses (Grace, *et al*., 2006). In view of the vast extent of grasslands and rangelands and the degraded nature of large areas of these systems, the potential to sequester carbon through improved management is significant. Such management practices include restoring organic matter to soils, reducing erosion, and decreasing losses resulting from burning and overgrazing. The capacity to sequester carbon depends on the climatic zone, the past history and status of the land resources such as soil and vegetation, and the opportunities available to change management practices (management techniques, competition with other land uses, economic tradeoffs, land tenure, social organization, incentives and political will). Raising livestock on dry lands through seasonal migration is a uniquely efficient way to make use of lands that are unsuitable for other forms of agriculture. Rangeland resources are typically heterogeneous and dispersed, with their variation tied to seasonal patterns and variable climatic conditions. Livestock keepers who inhabit these regions must contend with variable climatic conditions that regulate range productivity, among which rainfall patterns play a major role. Other relevant biophysical variables include soil quality, vegetation composition, fire events and disease outbreaks (Behnke and Scoones, 1993).

Soil properties change in time and space continuously (Rogerio, *et al*., 2006). Heterogeneity may occur at large scale (region) or at small scale (community), even in the same type of soil or in the same communityand investigation of its temporal and spatial changes is an essential tool for a sound management skill (Kavianpoor, *et al*., 2012). Determining soil variability is important for ecological modeling, environmental predictions, precise agriculture and management of natural resources (Hangsheng, *et al*., 2005; Wang, 2009). Therefore, it is crucial to understand nutrient status and subsequent adjustments in the management of the rangeland ecosystem. Mohammadi and Raeisi Gahrooei (2004) showed that spatial variation pattern of soil variables absolutely depends exactly on rangeland management history. Zhao (2007) reported that spatial variability of soil chemical and physical properties are affected by graze intensity. Geissen, *et al*. (2009) showed the significant impact of grazing pressure on soil characteristics. Silt percentage, available potassium and acidity (pH) had strong spatial dependence according to the results of Weindorf and Zhu (2010) and Kavianpoor *et al*. (2012). On the other hand, Tefera, *et al*. (2007), Moussa, *et al*. (2008), Kgosikoma (2011) and Kgosikoma, *et al*. (2013) suggested that livestock management systems do not have significant effect on soil properties. The impact of enclosure management on soil properties and microbial biomass in a restored semi-arid rangeland indicated that the contents of OC in different areas under study were approximately equal (Mureithi, *et al*. 2014).

Salinity and especially alkalinity can cause major impacts on plant production. Extreme values of soil pH, which affect the solubility of most of the elements necessary for plant growth, is an insidious problem in some regions. Soil pH affects the solubility of nutrients and uptake by plants (Rezaei and Gilkes, 2005). Of the changes that affect soil chemical properties, pH is considered very important as it influences the availability of plant nutrients (Bagayoko, *et al*., 2004; Ahmad, *et al*., 2011). Soil pH often affects plant community composition because plants differ in nutrient requirements and soil acidity or basicity tolerance. Soil pH is influenced by elevation because soil parent materials of higher pH occur at the lower elevation (Laughlin & Abella, 2007). Salinity is a dynamic soil property; it varies temporally and spatially with depth and across the landscape. Salinity varies primarily due to the process of leaching with topographic effects contributing to this variation (Corwin, *et al*., 2005). The acidic nature of the soils in the tropical rangelands has been indicated by Geissen, *et al*. (2009).

Rangeland sustainability is related to soil carbon and nutrient balance and the capability to maintain adequate soil conditions for water availability and root development (Noellemeyer, *et al*., 2006). Soil organic carbon plays an important role in ensuring good health of the soil environment and is critical in providing needed ecosystem services (Bationo, *et al*., 2007). Soil organic carbon improves soil physical, chemical, and biological properties for sustained plant growth (Li, *et al*., 2007). SOC plays an important role in supplying plant nutrients, enhancing cation exchange capacity, improving soil aggregation and water retention and supporting soil biological activity (Dudal and Deckers, 1993). Changes in soil carbon can occur in response to a wide range of management and environmental factors (Schuman, *et al*., 2002). Soil organic carbon is an index of sustainable land management and may offer further insight into fertility changes (Barrios *et al*., 1996; Nandwa, 2001; Du Preez and Snyman, 2003). Piñeiro, *et al*. (2010) suggested that soil carbon can decrease, increase or not change depending on the ecological condition. Furthermore, Dabasso, *et al*. (2014) suggested that lack of significant impact of livestock grazing on carbon stock should be understood in the context of semi-arid ecosystems with annual precipitation of 400 to 750 mm.

Phosphorous is the most limiting mineral to productivity of grazing animals throughout the world because of low availability to range plants and loss through soil erosion (Holechek, *et al*., 1998; Akhtar, *et al*., 2007). In most cases, P is the major limiting nutrient due to its fixation by Al and Fe oxides. The amount of available P has been reported by Kassahun and Asfaw (2008) to be ranged from absolute deficit to excess levels. Geissen, *et al*. (2009) observed that there was absence of P limitation in the rangelands unlike described for other tropical soils (Agele, *et al*., 2005). Bustamante, *et al*. (2006) indicated that when microbial activity is more intense in the soil it affects P dynamics strongly and P may also be mineralized at higher rates during the wet season. Brewere (1995) suggested that burning increases soil phosphorus levels, unlocking nutrients to the soil and making them available to the plants. Salinity is a dynamic soil property; it varies temporally and spatially with depth and across the landscape. Based on their assessment on impact of land use types on soil acidity in the highlands of Ethiopia, Endalew, *et al*. (2014) suggested that although exchangeable Mg, K and Ca concentrations rated moderate to high, their availability may be limited due to the acidity of the soil. Endalew, *et al*. (2014) stated that availability of K may be affected due to soil acidity in grazing lands.

2.6. Rangelands for sustainable use

Definition of sustainability: To anthropologists, cultural ecologists, and human rights advocates, sustainability means the ability of a people to preserve and defend its way of life. For pastoralists in particular, this means maintaining livestock productivity, defending their rights and access to water and grazing resources, and ensuring political and economic security

Sustainable management of arid and semiarid landscapes in Africa requires an understanding of interactions among environmental processes, socio-cultural components and local livelihood systems across both temporal and spatial scales (Behnke and Scoones, 1993; Fernandez-Gimenez, 2000). The use of local ecological knowledge, traditional management and community based knowledge indeed might be a key element for sustainable management and preservation of indigenous vegetation in the arid landscapes of Africa (Angassa, *et al*., 2012). This will accomplished through seasonal mobility of herds, preservation of dry season grazing and improved livestock marketing, and that failure to do so can result in far-reaching consequences for rural communities.

The traditional management systems in the drylands of Africa must be responsive to variability and uncertainty. Pastoralists' knowledge of species, ecosystems and climate form the basis for sustainable land management. Management strategies include seasonal movement of indigenous people (Ganya, *et al*. 2004), use of tree leaves and pods during dry seasons, burning of old pastures, and feeding on crop residues. Nomadic livestock herding has often been blamed for land degradation and threatening biodiversity, especially in the past. The case for mobility as a rational strategy for sustainable dry lands management has recently been established (Behnke and Scoones 1993) and mobility is probably the single most important element in the traditional management and knowledge systems of pastoral cultures in arid areas. Today, the contribution of mobile pastoralism to biodiversity conservation and to national economies is gaining greater recognition among social and natural scientists and development practitioners. Recent initiatives such as the "Dana Declaration on Mobile Peoples and Conservation", the development of a "Worldwide Initiative for Sustainable Pastoralism" and the support to the establishment and strengthening of the "World Alliance of Mobile Indigenous Peoples" represent this new recognition.

In many East African pastoral communities, selection of grazing sites is aided by scouts, who report on the condition of distant pastures, estimating how long the fodder and water will sustain a given number of livestock. In Sudan for example, herds are not grazed at random, but in sites selected to be the best available, while sites in poorer condition are left to regenerate (Barrow, *et al*. 2007). Conservation and sustainable use of arid and semi-arid biodiversity depends on significantly improved recognition and valuation of dryland biodiversity (Davies, 2012). An integrated conservation and development strategy will depend on recognition of both natural and agricultural biodiversity, and will sometimes require compromises to ensure that both are protected. Recognition of this diversity will be integral to developing more sophisticated conservation and sustainable development strategies that recognize the conservation value of multiple land-use systems. Dryland conservation strategies will increasingly look at using protected area status as a mechanism for protecting both biodiversity and environmentally-friendly farming systems. It will also look beyond protected areas to strengthen conservation in sustainably managed agricultural landscapes, for example through greater legitimization of indigenous and community conserved areas.

Pastoralism is typically based on local management systems for the sustainable use of wild and domesticated species. Grazing land management, especially in drought-prone areas, is a complex process requiring a balance between the use of water, food, fodder, fuel, etc. As users of grazing lands who are reliant upon the continued provision of such ecosystem services, pastoralists have a unique knowledge of how a balance between conservation and sustainable use can be achieved and maintained (Barrow, *et al*. 2007). In addition to seasonal and annual changes in use patterns, pastoralists are also able to quickly respond to perturbations. At the pasture scale the role of pastoralists as providers of ecosystem services that support biodiversity is now recognized (Barry, 2011). Because of their close historical connections with biodiversity, pastoralists also benefit from the cultural services provided by the ecosystems in which they live (Hodgson, 2000). This is often reflected in local management practices which largely emphasize long time horizons in decision-making in order to maintain culturally important elements of the ecosystem. For example, in Rajasthan India, Raika and Rabari pastoral people use local decision-making processes to sustainably manage mixed livestock herds to produce meat and milk (Blench, 2000). Where traditional pastoral livelihoods and management practices are replaced or restricted, however, the degradation of critical ecosystem services often follows.

Many pastoral systems are good examples of the application of the ecosystem approach. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems. Through its twelve principles, the ecosystem approach balances production and economic considerations with conservation and the maintenance of ecosystem services. The ecosystem approach also recognizes the importance of involving all stakeholders in decision-making and of decentralizing management to the lowest level possible (SCBD, 2004).

As a result of changing policies (e.g. affecting pastoralists' land and water access), continuing biodiversity loss, population growth, and accelerating climate change, the future of pastoralism and the role that it will play in biodiversity conservation and sustainable use remains unclear. Existing constraints to pastoralism, including exposure to droughts, and pest and disease outbreaks, are unlikely to diminish and may, in many cases; increase due to climate change.Progress towards environmental resiliency will originate from basic adjustments in local people's beliefs about their environment (Salem, 2007). Furthermore, establishing sound natural resource management will necessitate the participation of local users, due to their experience and intimate knowledge of their local environment passed on through generations (Bolling and Schulte, 1999; Fernandez-Gimenez, 2000). It is also widely recognized that local knowledge systems have been largely overlooked by researchers until very recently (Salem, 2007). Novel management approaches to the sustainable use of arid landscapes in Africa can also provide opportunities for local people to explore feasible and alternative livelihoods while maintaining the diversity and social values of their culture and landscape. Overall, the effective rehabilitation of African arid landscapes must entail a novel combination of policies and technologies that draw from both the scientific approach and the participation of local people in research and development activities.

Healthy grasslands are still achieved in drylands by bunching the stock into large herds and moving them frequently. Controlled grazing allows for more even distribution of dung and urine that can enhance soil organic matter and nutrients for plant productivity thus regenerating grasslands and improving livestock production simultaneously.Overgrazing is a function of time (grazing and recovery) and not of absolute numbers of animals it results when livestock have access to plants before they have time to recover. Compromised root systems of overgrazed plants are not able to function effectively. Unmanaged grazing or complete exclusion from grazing often will lead to desertification and loss of biodiversity in all but high rainfall areas (Jones, 2006). In medium-to-low rainfall areas, grasses which are not grazed can become senescent and cease to grow productively (McNaughton, 1979). Niamir-Fuller (1999) also notes that grassland productivity is dependent on the mobility of livestock and herders, the length of continuous grazing on the same parcel, the frequency with which the patch is re-grazed, dispersion of animals and herds around the camp, and the interval during which the patch is rested. These insights are consistent with the observed practices of traditional pastoralist communities across the world (Nori, 2007).

Land and plants respond differently to management tools, depending upon where they are found on the 'brittleness' scale. Brittleness is based on the distribution of moisture throughout the year.Based on these principles, a planned grazing method has been developed to: improve soil cover, increase water infiltration/retention, improve plant diversity/biomass, control the time the plant is exposed to grazing, increase animal density and trampling, distribute dung and urine, and improve livestock quality and productivity while maintaining grasslands with livestock. For example, Thurow, *et al.* (1988) showed that water infiltration increased under moderate, continuous grazing, while it decreased to some extent under short-duration grazing and even more under heavy continuous grazing over a 6-year period.

Non-equilibrium systems, in which rainfall timing and distribution are highly variable, are found in arid and semi-arid environments. In these areas, it has been noted that extreme variability in rainfall may have greater influence on vegetation than the number of grazing animals (Behnke, 1994). Grazing management in these ecosystems requires adaptive planning – the use of guidelines and principles in a continuous iterative process instead of prescripts such as uniform stocking rates. This does not imply that the concept of carrying capacity has been rejected. However, continuous monitoringof livestock productivity and range condition and productivity, and learning lessons from experience and practice can provide the framework that will allow an appropriate response to adapt to changing circumstances (climatic and socioeconomic). In this regard, Niamir-Fuller (1999) points out that pastoralists can maintain higher populations of herbivores sustainably if they have ensured and flexible access to the different habitats and resources in a given area.Grazing can be considered a management tool to enhance the vigor of mature perennial grasses by increasing their longevity and promoting fragmentation of decaying, over mature plants by encouraging basal bud activation, new vegetative and reproductive tiller formation as well as seed and seedling production. The positive effect of grazing results from the effect that it has on species composition and litter accumulation (FAO, 2004).

The role of traditional land-use systems, such as agro forestry and pastoralism, in providing food and income as well as protecting biodiversity will be strengthened and will become integral to national conservation strategies. Similarly, innovative agricultural systems that protect and support ecosystem services, such as new forms of conservation agriculture, will be protected for their environmental benefits. The importance of indigenous knowledge and institutions for environmental custodianship will receive greater legitimacy and support from government and will become the anchor of integrated agricultural development and conservation approaches.

Biodiversity is important at three levels: the genetic level, the species level and at the level of ecosystems (SCBD, 2010). Because of the close links between pastoral peoples, the ecosystems which they live, and the animals that they breed, pastoralism has a significant role to play in the conservation and sustainable use of biodiversity at each level.

Genetic Level: Pastoralists often rely on locally adapted livestock breeds and crop varieties that are able to resist disease outbreaks, drought and other pressures, including climate change.

Locally adapted livestock breeds are capable of walking long distances and surviving drought which enables effective management of systems that demand mobility and drought tolerance. In many areas, pastoralists are the only groups actively working to maintain the genetic diversity of local breeds.

Species Level: Pastoralists contribute invaluable local knowledge to the management of biodiversity at the species level. For example, a study by the League for Pastoral Peoples and Endogenous Development (LPPED and LPPS, 2005) gathered information on 52 different grass species in China based on their location, distribution and nutritional value. Furthermore, in recognizing the value of a wide variety of species, a number of pastoral communities have management systems in place to ensure the conservation of important species, which may otherwise be overlooked. By retaining species and management practices that have evolved in parallel with the local environment, pastoralists retain important species interactions (e.g. herbivores, host-parasite, and nutrient cycling), which benefit many wild species of plants, birds and insects.

Ecosystem Level: Many ecosystems have evolved as a result of interactions with grazers. For example, pastoralism maintains a patchwork of habitats including open areas, which are important for nesting birds. Furthermore, livestock are important contributors to food cycles. Since pastoralism is so heavily reliant upon the continued provision of ecosystem services, traditional management systems naturally adopt many of the principles that target the maintenance or enhancement of ecosystem health. The ecosystem approach also recognizes the importance of involving all stakeholders in decision-making and of decentralizing management to the lowest level possible (SCBD, 2004).

2.7. Impression of plant diversity at local and regional landscape level

There is now sufficient evidence that the effects of species exert on one another in a local habitat patch often depend on the order and initial abundance in which species arrives at regional level (Sutherland, 1974; Drake, 1991; Chase, 2003). Known as priority effects (Slatkin, 1974), such historical possibility in local community assembly is increasingly recognized as a major factor influencing species diversity (Fukami and Nakajima, 2015). In particular, recent research has shown that local priority effects can enhance beta diversity, i.e., the variation in species composition among local communities, by driving communities onto divergent successional trajectories (e.g., Chase, 2010; Martin and Wilsey, 2012; Fukami and Nakajima, 2013). Founded in large part on MacArthur and Wilson's (1967) theory of island biogeography, much of this research has traditionally assumed an external species pool. That is, immigrants entering local patches are drawn from a regional pool whose species composition is static and is not influenced by local community dynamics. However, at large spatial and temporal scales, the regional pool consists of immigrants originating from a collection of local patches themselves (Mittelbach andSchemske 2015). In other words, the regional pool is not external, but internal as depicted by the metacommunity concept (Fukami, 2005; 2015).

To explain species diversity at these scales, it is therefore necessary to understand how a species pool can be maintained as a collective result of local community dynamics. This task is particularly challenging when species engage in inhibitory priority effects, where species that are initially common hinder colonization by competing species (Shurin, *et al.*, 2004). In many cases, species are likely to arrive at a newly created or disturbed patch in proportion to their regional abundances within the metacommunity. This correspondence between regional frequency and arrival probability can result in neutral population dynamics at the regional scale (Taneyhill, 2000) with all but one species eventually drifting to regional extinction. In other cases, regionally common species can benefit disproportionately from the local priority effects and regionally rare species tend to become even rarer and eventually disappear from the region (Shurin, *et al.*, 2004).

Thus, to maintain both local priority effects and a diverse regional pool of species, there has to be a mechanism that buffers species from regional extinction. In a pioneering study, Shurin, *et al.*, (2004) suggested that spatial environmental heterogeneity could be one such mechanism. In their specific model, patches differ in the concentrations of two essential resources. Two species may then engage in priority effects in patches with relatively balanced resource composition while there is strict competitive exclusion of one or the other species in patches with more extreme resource composition. The extreme patches then serve as refuges from which species continue to disperse into patches where priority effects occur. In this sense, invoking spatial refuges is conceptually no different from assuming an external species pool. As a consequence, it remains unknown whether regional species diversity can be maintained in the presence of local priority effects without recourse to an external species pool.

The concept of a species pool is commonly used in theoretical and applied studies in ecology, biogeography and conservation biology (Connor and Simberloff, 1978; Ricklefs, 1987; Shurin and Srivastava, 2005; Lessard, *et al.*, 2012; Cornell and Harrison, 2014; Benjamin, *et al.,* 2015). Others also identified as priority effects (Slatkin, 1974), the historical contingency in local community assembly is increasingly recognized as a major factor influencing species diversity (Fukami and Nakajima, 2015). Similarly, recent research has shown that local priority effects can enhance beta diversity, in other words, the variation in species composition among local communities, by driving communities onto divergent successional paths (Chase, 2010; Martin and Wilsey 2012; Fukami and Nakajima, 2013). A variety of models have previously been employed to describe or explain the local–regional relationship that the species pass through different biotic and abiotic filtering. Some of these models relate local–regional relationships to other ecological patterns, such as the power dispersal filtering (Marteinsdo´ttir and Eriksson, 2014a), environmental filtering abilities (Francesco de Bello, 2013; Benjamin, 2015), trait based filtering (Lars, *et al.* 2008; Marteinsdóttir and Eriksson, 2104b) Biotic filtering (Pearson, *et al.* 2014) and others.

A species pool is the set of species that could potentially colonize and establish within a community (Lessard, *et al*., 2012). Species pools have proven especially useful for testing whether the composition of communities differs from random expectation (Connor and Simberloff, 1978), estimating the influence of regional richness on local species richness (Ricklefs, 1987), testing for species saturation (Shurin and Srivastava, 2005) and understanding how different factors and processes of community assembly are linked to one another (Götzenberger, *et al*., 2012). More recently, ecologically explicit definitions of species pools have been suggested as a promising way to quantify the influence of evolutionary and historical processes on local community assembly (Algar, *et al*., 2011; Lessard, *et al*., 2012; Carstensen, *et al*., 2013).

In a pioneering study, Shurin, *et al*. (2004) suggested that spatial environmental heterogeneity could be one such mechanism. In their specific model, patches differ in the concentrations of two essential resources. Two species may then engage in priority effects in patches with relatively balanced resource composition while there is strict competitive exclusion of one or the other species in patches with more extreme resource composition. The extreme patches then serve as refuges from which species continue to disperse into patches where priority effects occur. In this sense, invoking spatial refuges is conceptually no different from assuming an external species pool. As a consequence, it remains unknown whether regional species diversity can be maintained in the presence of local priority effects without recourse to an external species pool. The goal of this paper is to suggest that this maintenance is possible when species traits responsible for priority effects evolve rapidly.

In addition to the concept of a species pool, another central idea in community assembly theory is the concept of a "filter" that allows some species to pass through while serving as a barrier to unsuitable species as they arrive and attempt to establish at a site. This concept is first seen in the study of succession following disturbance, when Nobel and Slatyer (1977) describe an "environmental sieve" during succession. This concept was used extensively throughout the development of plant community assembly studies, often in terms of a "filter" that only permitted particular phenotypes to establish and persist (van der Valk, 1981; Woodward and Diament, 1991). As a result, for plants to establish in a local species pool of possible colonizers from the region, it must pass through a series of filters. Therefore, the diversity of species into local communities has been conceptualized as a series of filters selecting species according to their traits from a regional species pool into a local habitat (Keddy, 1992). However, in researching the influence of various processes on plant diversity, traditional community ecology is generally limited to local processes such as competition, predation, local environment, and mutualism in communities (Cornell and Lawton, 1992; Zhang and Jiang, 1997; Belyea and Lancaster, 1999; Chesson, 2000).

Traditionally, ecologists have used the concept of the species pool for two distinct purposes: as a way to test whether the structure of communities differ from a random expectation (Connor and Simberloff, 1979); and as a way to estimate the influence of the size of the species pool on local species richness (Ricklefs, 1987).To explain species diversity at these scales, it is therefore necessary to understand how a diverse species pool can be maintained as a collective result of local community dynamics. This task is particularly challenging when species engage in inhibitory priority effects, where species that are initially common hinder colonization by competing species (Shurin, *et al.,* 2004). In many cases, species are likely to arrive at a newly created or disturbed patch in proportion to their regional abundances within the metacommunity.

This correspondence between regional frequency and arrival probability can result in neutral population dynamics at the regional scale (Taneyhill, 2000), with all but one species eventually drifting to regional extinction. In other cases, regionally common species can benefit disproportionately from the local priority effects and regionally rare species tend to become even rarer and eventually disappear from the region (Shurin, *et al.*, 2004). Thus, to maintain both local priority effects and a diverse regional pool of species, there has to be a mechanism that buffers species from regional extinction.

2.8. Rangeland and Pastoralism in Ethiopia

The drylands of Ethiopia are dominated by rangeland based livestock production systems known as pastoralism and agro-pastoralism and represent a significant sector of the national agriculture in the country (EARO, 2002). For example, pastoralists represent approximately 37% (26.6 million) of the national population that include an estimated 12.24 million (17%) mobile pastoralists and 14.4 million (20%) agro-pastoralists. Mobile pastoralism is dominant in the arid and semi-arid areas in the eastern, northeastern and southeastern parts of the country, while agro-pastoralism represents an increasing practice in the semi-arid areas in the northwestern, southern and eastern parts of the country. In general, they represent the major pastoral constituency in the Horn of Africa (Amaha, 2002).

Pastoral communities represent 10% of Ethiopia's population and approximately 40% of the land area of Ethiopia is considered to be under pastoral production (Helland, 2006). They tend to live in the drier and hotter lowlands of the country: these include the whole of Somali region (accounting for 57% of the pastoralists in Ethiopia) and the Afar region (26% of Ethiopian pastoralists). The *Borena* and *Karrayu* pastoralists in Oromiya Regional State together account for about 10% of the total pastoral communities in Ethiopia. The remaining 7% of Ethiopian pastoralists inhabit the lowlands of the Southern, Gambella and Beni Shangul regions (Sandford and Habtu, 2000, RPPACC, 2011). Ethiopia is home to Africa's largest livestock population, which is largely concentrated in pastoralist areas. Pastoralist communities, drawing upon their local knowledge of livestock rearing, subsist largely from the sale of livestock and livestock products (SCBD, 2010). Pastoral production makes an immense contribution to the national economy by raising 40% of the cattle, 75% of the goats, 25% of the sheep, 20% of the equines and 100% of the camels (Yacob, 2000). The total direct economic contribution of pastoralism to the Ethiopian economy (through the production of milk, meat, skin, hides, etc.) is estimated at US$ 1.53 billion, which accounts for about 6% of the agricultural Gross Domestic Product GDP per annum (Berhanu and Feyera, 2009). The pastoral and agro-pastoral production system also represent approximately 45-55% of the cattle, 75% of the small ruminants, 20% of the equines and 100% of the camels of the total national livestock population. Accordingly, they contribute about 50% to the national agricultural (GDP) and 90% of the annual hard currency earnings from live animal exports (EARO, 2002).

2.9. The Indigenous knowledge of pastoralists in rangeland management

Pastoralists have managed their production system for many centuries, accumulating detailed knowledge of the environment of their grazing landscape (Oba and Kotile, 2001; Mapinduzi, *et al.*, 2003). Pastoralists' management practices are ecologically adapted to local environmental conditions (Fernandez-Gimenez, 2000). Indigenous or local knowledge can be defined as skills, practices and technologies that are an integral part of the production system in a specific culture (Desta, 2009, Dika, 2016).Pastoralists have local knowledge on a large diversity of plant species that provide food for livestock (Mapinduzi, *et al*., 2003). Local knowledge is widely acknowledged to be a valuable source of data on the historical distribution of species which are generally difficult to assess using classical ecological methods (Lykke, *et al*., 2004) and especially in the case when other historical and ecological information is not available (Sulieman, *et al*., 2012) though these knowledge encountered constraints of perceived to be locally specific, qualitative and lacks impartiality (Oba and Kaitira, 2006). They are area-specific skills and practices concerning natural resource management, human and animal health, etc. developed by indigenous people over centuries. Pastoralists assessed land degradation at the scales varying from patches of few meters to landscapes of several hundred hectares, while ecologists assessed degradation at ecosystem scales (Oba, 1994). Thus, the first step to integrate the ecological and indigenous ecological knowledge methods is to make environmental change assessments at similar scales (Kovacs, 2000; Fernandez-Gimenez, 2000; Berkes, *et al*., 2000).Therefore, it is important to take advantage of indigenous institutions, environmental knowledge and traditional management practices (Desta, 2009). Turner, *et al.*, (2000) suggested that traditional knowledge of the indigenous people was fundamentally important in the management of local resources. Other studies (Fernandez- Gimenez, 2000; Angassa and Oba,

2008) documenting local ecological knowledge of rangeland resources have provided useful information for the development, sustainable utilization and conservation of natural resources. Therefore, pastoralism is considered the most economically, culturally and socially appropriate strategy for maintaining biodiversity in rangelands landscapes.

Pastoralists are experts at maximizing the use of rangelands and, moving between seasonal grazing areas, they will achieve high levels of productivity taking strategic advantage of different forage and water sources as they become available. Pastoralists understand the heterogeneity of arid environments and use appropriate management practices such as mobility and mixed stocking to adapt to such environments (Thomas and Twyman, 2004; Angassa and Oba, 2008). Transhumance pastoralism is based on more or less regular seasonal and cyclical migration of varying degrees between complementary ecological areas (Sulieman, 2013). Their mobility is a key strategy to gain access to seasonal availabilities of high quality forage and to reduce the vulnerability of livestock to local environmental risks (Kaimba, *et al.*, 2011). Such mobility enables the exploitation of heterogeneous environments in space and time (Solomon, *et al.*, 2007). The pastoral regions of Ethiopia, as elsewhere in Africa, have a fragile environment and unpredictable weather (PFE, IIRR and DF, 2010). Many researchers studying pastoral systems have concluded that extensive livestock production on communal land is the most appropriate use of arid and semi-arid lands in Africa (Behnke, *et al.*, 1993; Scoones, 1995). Nori (2007) argues that the mobility and flexibility of pastoral systems enables them to make the best use of the patchy and fragile environment. When compared to ranching models, pastoral systems are found to be more productive per unit area due to the ability of pastoralists to move their herds opportunistically and take advantage of seasonally available pastures (Sandford,1983) and to be more economically feasible than either sedentary or ranching systems (Niamir-Fuller, 1999). The driving forces behind land degradation in dryland ecosystems, however, can be complex. Thus, local ecological knowledge of climate change must be integrated with the scientific approach in order to understand the causes and consequences of land degradation. Such an approach, which involves the participation of the local community, has proven to be effective in devising proper management system for the sustainable use of arid landscapes (Grice and Hodgkinson, 2002).

Pastoralists' perception and ecological knowledge of vegetation changes are often ignored in studies aimed to improve management of rangelands (Roba and Oba, 2009). The significance of traditional range management in the arid lands of East Africa is rarely considered in the research conducted by range ecologists in the past. The presumed linkage between pastoralists land use and degradation of grazing lands (Sinclair and Fryxell, 1985) have mostly relied on opinions given by ecologists, while indigenous ecological knowledge of pastoralists, which is perceived to be unscientific is largely ignored (Pierotti and Wildcat, 2000). In contrast to the official view, the pastoralists have developed elaborate methods for assessing rangeland conditions and trends (Oba, 1994). Whereas natural resource managers ignored indigenous ecological knowledge for what they considered to be lack of universal appeal needed for developing common grazing models, indigenous ecological knowledge utilized by different pastoral peoples worldwide has striking similarity in the way information on grazing lands is analyzed and landscape level degradation assessed (Fernandez-Gimenez, 2000, Oba, 1994). The pastoralists have perceptions of livestock grazing suitability and potential grazing capacity of individual landscapes (Oba, 1994; Coppolillo, 2000; Fernandez-Gimenez, 2000).

Despite this, the present management of rangelands to a large extent is dependent on pastoralists' indigenous knowledge of such areas (Mapinduzi, *et al*., 2003). Nowadays, many range scientists came to realize that pastoralists have extensive ecological knowledge (Berkes, *et al*., 2000; Ladio and Lozada, 2009). Traditional ecological knowledge is unique to different places and communities (Fernandez-Gimenez, 2000), and even to different individuals within a community (Kgosikoma, *et al*., 2012). Examining such variability in the pastoralists' ecological knowledge under different cultural and environmental conditions is expected to provide a broader understanding of ecosystem dynamics (Kgosikoma, *et al*., 2012). Shifts in rainfall patterns and frequent droughts, which are indicators of the climate change, cause massive loss of livestock in the region (Oba, 2001; Angassa and Oba, 2007). As a whole, widespread environmental degradation exacerbates the advancement of global climate change and furthers the reduction of ecosystem productivity (Berkes, *et al.*, 1998). The challenges in finding environmentally sound and culturally acceptable natural resources management practices thus lead researchers to consider community-based-knowledge (Berkes, *et al.*, 1998; Bolling and Schulte, 1999; Fernandez-Gimenez, 2000; Mapinduzi, *et al.*, 2003; Oba, 2001; Oba and Kaitira, 2006; Angassa and Oba, 2008). In addition, there is little data on indigenous vegetation in arid African landscapes and its historical changes. Hence, the knowledge of local people becomes indispensable in order to fully understand long term changes in indigenous vegetation. Local awareness of environmental issues is fairly comprehensive (Bolling and Schulte, 1999) and effective in sustainable development research and application (Bowman, 2002; Dale and Beyeler, 2001). Pastoral community of Ethiopian Somali region, land allocation or fencing are enclosures which are reserved for lactating, sick or young animals, so that these animals do not have to travel the much larger distances traveled by the rest of the herd for pasture particularly in the dry season.

2.10. History and development of an enclosures in Ethiopian Somali region

Enclosure is an ecological management measure that excludes grazing and damage practices, allowing the grassland to enter a state of self-recovery (Lunt, *et al.*, 2007). Rangeland enclosures and related issues of property rights in African grazing lands have received research attention since the 1980s (Behnke, 1985; Behnke, 1988), indicating gradual changes in the property right regimes. The changing scenarios make it important to assess enclosures within pastoral innovation systems in order to bridge the knowledge gap that exists in this aspect. Enclosure is one of the most important trends practiced by pastoralist in east African rangeland (Graham, 1988). The development of enclosures in region refers to the expansion of permanent settlements around rangeland water, degradation of pasture resources, commercialization and inter and intra-clan competition. One research also shows; the increasing market value of enclosure over time (as feed shortage encouraged people to sell grass from enclosed land), the need to conserve pasture as a dry season feed reserve, as well as the diversity of decision making rules and institutions and requirements necessary to secure rights to enclose land (Talasan; 2009). Sugule and Walker (1998) describe how the practice of individuals fencing former communal grazing land emerged in Aware in the 1980s, and link this to increasing pressure on grazing land due to uncontrolled growth of water points and settlements. Some enclosures were established to conserve fodder for own livestock, while others were for crop cultivation as people tried to supplement their livelihoods. Gomes (2006) also describes a process whereby the proliferation of enclosure in the Haud area in the 1990s led to increasing settlement and the rise of crop cultivation to supplement pastoralism, which in turn resulted in land privatization and the spread of rangeland enclosures in the Haud. The Haud is a historically important grazing area for Somali pastoralists, stretching from Jijiga along the Somali border up to Gashamo and beyond.

Most of the rangeland in Harshin is already permanently divided and enclosed by individuals. Earlier study in 2009 estimated that 80% of pasture lands in Harshin are enclosed (Talasan, 2009). Tufts research for this review found that in the Dollo area; almost all private enclosures (*sheromo*) are established within the farmland and along the Dawa and Genale rivers (Gezu, 2011). Also in 2011 the government initiate pastoralist to establishment of more area enclosures in Kabrabaya, Degehabur, Arara, Gashamo, Adadle, Wardher and Kebridaharto rehabilitate and improve degraded rangelands previous decades. Also in northern Somali region where the study focuses, the enclosurehave been widely practiced by Shinile communities. The enclosures would be managed by committees including customary leaders and local government, and would be fenced and guarded. SoRPARI has also submitted a proposal for the enclosure of 1,000 hectares of degraded rangeland in five Woredas for research and development purposes (SoRPARI, 2011).

In the Somali regional state rangeland today, grazing reserves exist in various forms. One is the communal enclosure where a group of villages reserve pastures on communal basis. The second type is the enclosures used by the community but introduced or supported by NGOs. The third category is private enclosure which is not common like others. The development of enclosures in region refers to the expansion of permanent settlements around rangeland water, degradation of pasture resources, commercialization and inter and intra-clan competition. One research also shows; the increasing market value of enclosure over time (as feed shortage encouraged people to sell grass from enclosed land), the need to conserve pasture as a dry season feed reserve, as well as the diversity of decision making rules and institutions and requirements necessary to secure rights to enclose land (Talasan, 2009). Sugule and Walker (1998) describe how the practice of individuals fencing former communal grazing land emerged in Aware in the 1980s, and link this to increasing pressure on grazing land due to uncontrolled growth of water points and settlements. Some enclosures were established to conserve fodder for own livestock, while others were for crop cultivation as people tried to supplement their livelihoods. Gomes (2006) also describes a process whereby the proliferation of "berkado" in the Haud area in the 1990s led to increasing settlement and the rise of crop cultivation to supplement pastoralism, which in turn resulted in land privatization and the spread of rangeland enclosures in the Haud. The Haud is a historically important grazing area for Somali pastoralists, stretching from Jijiga along the Somali border up to Gashamo and beyond.

The enclosures would be managed by committees including customary leaders and local government, and would be fenced and guarded. SoRPARI has also submitted a proposal for the enclosure of 1,000 hectares of degraded rangeland in five Woredas for research and development purposes (SoRPARI, 2011). The ecological objectives of work on enclosures are to rehabilitate bush infested and degraded rangeland by enhancing recovery in place where soil degradation and overgrazing are common outside the enclosures. Those motivate pastoralist of Somali region to construct their enclosure. Most of the rangeland in Harshin is already permanently divided and enclosed by individuals. One study in 2009 estimated that 80% of pasture lands in Harshin are enclosed (Talasan, 2009). Tufts research for this review found that in the Dollo area; almost all private enclosures (*sheromo*) are established within the farmland and along the Dawa and Genale rivers (Gezu, 2011). Also making enclosure were the common practiced of Afdem Shinile, Kabrabaya, Degehabur woreda community in previous decades.

Table 1: Timeline of key events related to the development of enclosures in Ethiopian Somali region

Period	Key events
1950-1955	•In Harshin, lack of water for cattle led to a big increase in the construction of birkads; in some areas this led to conflict among clans.
1962	•The establishment of large private farms and the first private enclosures in the region as land is divided between different clans (Abdulahi Farah, Ugas Mohamud, and Sultan Gallool Elmi) in a government led attempt to resolve inter-clan conflict.
1974-1977	Ethio-Somali war; outflow of Ethiopian Somalis to Somalia; start of the *Derg* regime; • *Dabadheer drought* – a long lasting, unforgettable drought. • Cooperative enclosures started in the ‘Haud’ area, based on clan ownership. The Haud is a historically important grazing area for Somali pastoralists, stretching from Jijiga along the Somali border upto Gashamo and beyond.

	• Government enclosures were started by the *Derg*; these were mainly grazing reserves for commercial producers (involved in fattening or feed production). • Resettlement policies were introduced for people affected by the drought. • Kebeles were formed and as Kebele leaders became more powerful, traditional leaders were weakened. • Large scale rangeland development projects started, with the construction of big ponds.
1983*	• Critical drought led to massive livestock mortality; Private enclosures were initiated by wealthier households who split their family to allow them to feed milking animal's atthe main settlement (Shinile).
1984-1988*	Herds recovered and seasonal movement was reinitiated; the majority of the private enclosures were abandoned (Shinile).
1988-1991	Somali civil war. Refugees and returnees returned from Somalia and claimed land for farming; • Massive deforestation as refugees tried to make a living from selling firewood • Development of ponds as well as shallow wells.
1991	EPRDF government and regionalization policy. Influx of people due to political support in Ethiopia for settlement and the allocation of farmland to returnees; • Non-Ethiopian Somalis also came to try to claim land. • Somali communities started to farm and become agro-pastoralists, mainly producing feed for their livestock. • NGO interventions on NRM started, along with awareness creation about degradation; enclosures were started as a means of rehabilitating rangeland • Huge camps were established for the refugees by NGOs and UNHCR; this was accompanied by massive deforestation as people sought an income from sale of firewood and charcoal making. • In Dollo, returnees enclosed dry season grazing lands around Dawa and Genale rivers for crop farming or production of pasture/fodder; host communities responded by enclosing more rangelands around the rivers.*
1995	• Establishment of cooperative societies and start of cooperative enclosures • Lands were enclosed for charcoal production.

1998*	• Record high rains • Some pastoralists planted their previous enclosures to take advantage of crop production (Shinille).
2000-2009	• Increasing settlement, linked to access to water points and other basic services such as health and education • Increase in number of privately owned enclosures, linked to government development interventions; usually on areas of reclaimed land • Increasing drought; Herds were depleted and the majority again stopped seasonal movement; Rangeland enclosure practice was reinitiated (Shinille)* • Drought destitute pastoralists became dependent on income from firewood/charcoal marketing; Others responded by enclosing more rangelands mostly close to settlement areas, to protect browse (Shinille)* • The practice of private enclosure expanded as crop farming expanded (Dollo)* • A number of communal enclosures were established away from the rivers with support of SC US (Dollo)*.
2010	• Emergence of MERET project and safety net 'donor led' enclosures, which are mobilizing people to establish area enclosures on a communal basis • SoRPARI/government develops plan for a 10,000 ha area enclosure across 6 districts in the region; the aim is mainly rangeland rehabilitation, including in the Haud area.

Source: PLI Policy Project; Review of Pastoral Rangeland Enclosures in Ethiopia (2011)

Note: Information marked with * is from Gezu Bekele's (2011) field work in Shinille and Dollo.

2.11. Significance of rangeland biodiversity in Ethiopian Somali region

The populations in Ethiopian Somali region greatly depend on biodiversity resources for their basic livelihood in many forms. Forest based activities supplement substantial income and employment opportunities for the society. The natural dry land vegetation provides firewood, fodder, food, soil cover, non-timber forest products and modifies the microclimate. Well over 90% of the Ethiopian Somali people construct their houses from wood and related forest products. Wood is the primary material used to make local household furniture (e.g. milk containers, water containers, troughs, spoons, plates etc. The most significant place of trees in relation to livestock is a supply of fodder. Moreover, medication of people and livestock is heavily dependent on the indigenous tree and shrubs. In the region, the collection and marketing of the natural gum and incense, fuel wood collection, charcoal making and their sell also contributes substantial income to many poor in the rural areas of the region. Apart from these visible economic contributions of the woodland resources, there, are other services such as soil and water conservation, nutrient cycling, and nitrogen fixation and improvement of microclimate for people and livestock, wildlife habitat and biodiversity conservation.

3. MATERIAL AND METHODOLOGY

3.1. Description of the study area

3.1.1. Geographical location

Ethiopian Somali Regional State is located between 4-11^{o}N and 40-48^{o}E, within the eastern and southeastern lowlands of Ethiopia. The total land area is about 327,000 km^2, equivalent to 30% of the national land area. This region is the second largest in Ethiopia with the population of 4.5 million (CSA, 2007) and it consists of nine administrative zones, 67 districts (Woredas).

The current study was conducted in Shinile Woreda, Shinile zone, 85 000 km^2 in size, which is located in the northern part of the Regional State (Fig. 2). Shinile Woreda is bordered by Dire Dawa district in the south, Erer Woreda in the southwest, Dambal Woreda in the south-east and Ayshia in north east. Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this Woreda has a total population of 67,652, of whom 36,398 are men and 31,254 women.

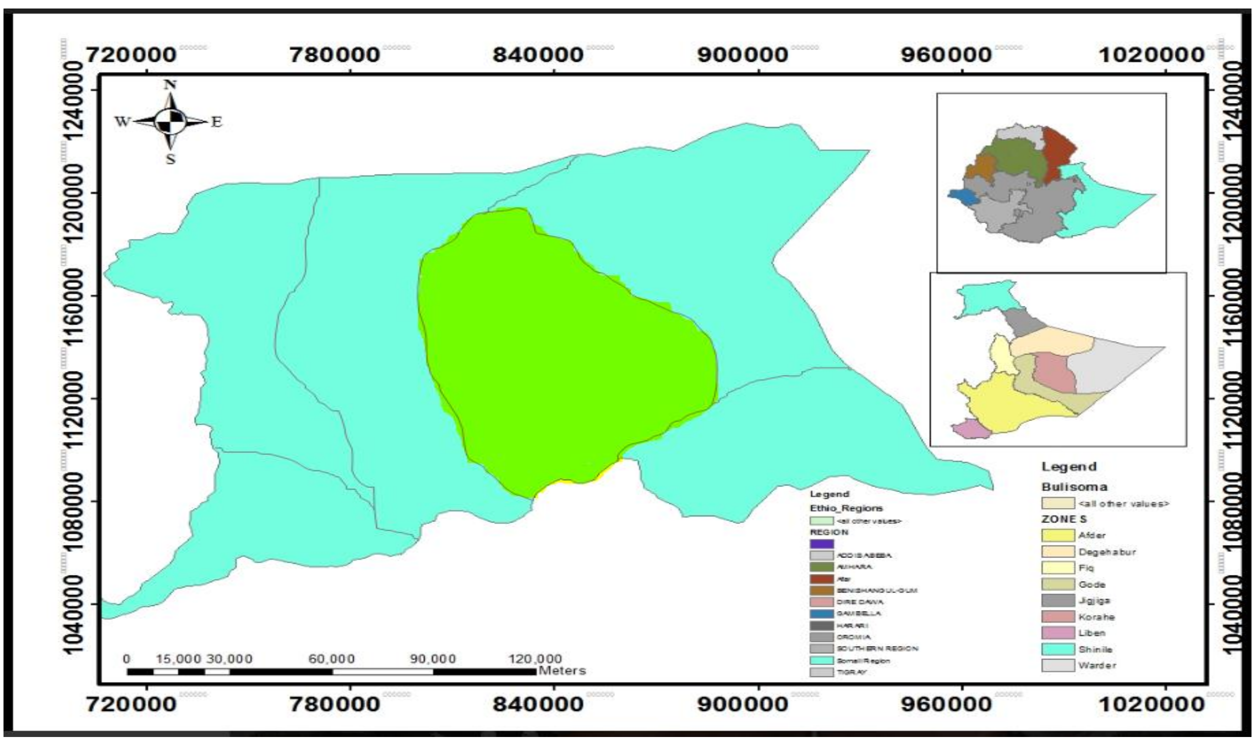


Figure 2: Map of the study area and sampling sites (the green one is specific study area Shinile Woreda)

3.1.2. Topography and Climate

According to the Shinile zonal Bureau of Agriculture (2003), the agro-ecology of the zone includes arid (60%), semi-arid (30%) and semi-desert and rocky (10%) areas. It falls within the Rift Valley plains with an altitude ranging between 450 and 1200 masl. The area is known for its hot climate and as a result annual plant growth periods are short, ranging between 40 and 65 days, which is inadequate to support crop agriculture without supplementary irrigation. Hence, the growth and maturity of annual and semi-annual grasses and browses are favored (ADPO, 2004). The rainfall is bimodal which include the short rainy season from March to April (2 months) and the main rainy season from July to September (3 months). The variation in the precipitation between the driest and wettest months is 108 mm. throughout the year; temperatures vary by 7.1 °C. The climate in Shinile is referred to as a local steppe climate. The average temperature is 27 °C in Shinile. The mean annual rainfall is 554 mm. The temperatures are highest on average in June, at around 28.9 °C. January is the coldest month, with temperatures averaging 21.65

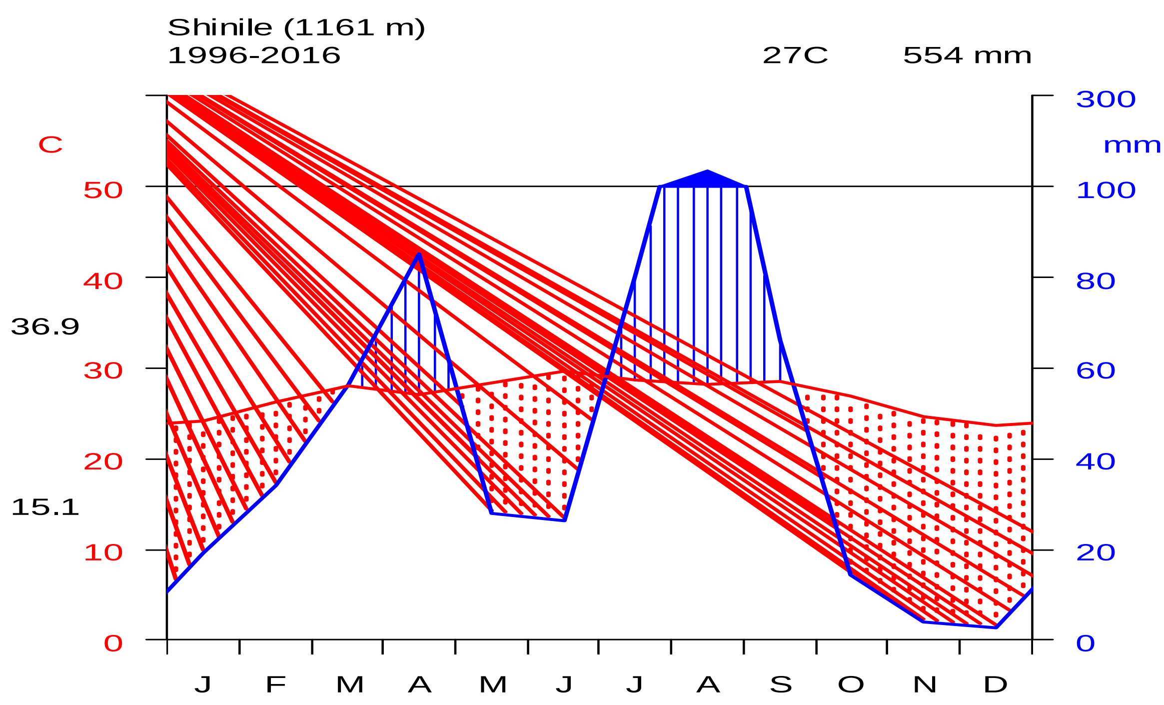


Figure 3: Climate diagram of Shinile Woreda

3.1.3. Soil

According to the FAO/UNDP (1984) classification of Ethiopian soil, the soil is classified as vertisols (heavy clay in areas of pronounced dry areas), mainly dark pellic vertisol and chromic vertisols and fluvisols (young soils developed in recent alluvial deposits). The soil classification for the open savannas also includes vertisols (mainly chromic vertisols) and fluvisols. The soil of the closed savannas includes nitosols (clayey red soils with argillic B horizon) and regosols without profile development and with loose soil material. According to SERP (1990), the soil texture for the rangelands of the Shinile Zone range between 4 and 60% clay, 10 and 50% silt and 40 and 60% sandy loam. The soil depth varied between 1.5 and 2 m for the clay soil of the grasslands, 1 to 1.5 m for the clay loam soil of the bush-grasslands and 0.5 to 1 m for the sandy loam clay soil of the bush lands.

3.2. Selection of the study sites and field layout

A reconnaissance survey was conducted in December 2015 to select the study site. Four sites were selected from four Kebele in Shinile Woreda for this study. A purposive selection of four enclosures and their surrounding open grazing areas were made. The first enclosure is located at $9^0$40’20’’N $41^0$50’60’’E and was used to understand the impacts of enclosure and localized effects of selected *Acacia* species on plant diversity and soil properties. The second enclosure islocated at$9^0$40’49’’N $41^0$50’46’’E and was used to determine seed quality and maternal body height of six selected species. The others sites were used to assess the impact of enclosure on plant diversity at local-regional species pool level. The sample were collected from two location at right and left side of Shinile town (Shinile and Marmarsa Kebles) where the communitieshavesettled.

3.3. Methods

3.3.1. Herbaceous plant and soil survey

3.3.1.1. Herbaceous sample collection and measurement

For plant sample collection, a total of 40 sampling site of 1mx1m were randomly located inside and outside of enclosure in our study site; 20 from inside enclosure and 20 in open grazing area. Inside the enclosure, 10 sampling plot were from under *Acacia* shade and the other 10 sampling plot were from nearby placesbut without *Acacia* shade. We did the same sampling methods in the open grazing area, i.e., 10 sample plots from under *Acacia* shade and 10 areas without a shade of *Acacia*. Herbaceous plant were collected from under canopies of *Acacia nilotica, Acacia senegal, Acacia tortilis, Acacia mellifera* and *Acacia nubica* at both insidethe enclosure and open communal grazing areas. Plants were collected from late August to mid-September 2016, a time when herbs flower and fruit. All plant species at inside enclosure under acacia (IEUA), inside enclosure without acacia (IEWA), outside enclosure under acacia (OEUA) and outside enclosure without acacia (OEWA) were counted and collected for further analysis. Plant samples were prepared according to the guidelines of the National Herbarium for Floras and Faunas of Ethiopia (ETH) (1987). Herbs were collected by carefully uprooting the plant using a shovel, together with above-ground parts such as stems, leaves, shoots, flowers, pods or seeds. Samples were pressed, dried and then transported to the ETH for identification by using annotated herbarium specimens and Flora of Ethiopia and Eritrea.

3.3.1.2. Soil nutrient status survey

For soil samples, the same plots used to collect plants were used (Section 3.3.1.1). Soil sample were also taken from under canopies of *Acacia nilotica, Acacia senegal, Acacia tortilis, Acacia mellifera* and *Acacianubica.* Soil was sampled at the four corners and a center of the 1m x 1m plot using 6 cm auger from the top 0 to 10 cm depth.All soil from each site were carefully kept in separatepaper bags and air dried for analysis by following(Okalebo *et al*., 2002). Soil samples of weight 0.25 kg were used for analyses of pH, electrical conductivity (EC), organic carbon (OC), organic matter (OM) available phosphorus (P) and exchangeable potassium (K).The analysis were conductedat Soil, Plant and Water analysis laboratory of Haramaya University.

3.3.2. Maternal body size measurement and seed collection of selected plant species

Inflorescences containing mature seeds (panicle or spike) of all six selected species were collected at IEUA, IEWA, OEUA and OEWA in Shinille Woreda, in September 2016. These species are *Aristida kelleri, Eragrostis cilianensis, Cenchrus ciliaris, Eriochloa fatmensis, Dactyloctenium aegyptium* and *Tragus berteronianus*. From all species *Eragrostis cilianensis, Cenchrus ciliaris, Eriochloa fatmensis* were the common species in thestudy area. However the other species such as*Aristida kelleri, Dactyloctenium aegyptium* and *Tragus berteronianus* are uncommon or less common instudy area (Table 4; Figure 4).We have selected the species based on their occurrence across the experimental sites. The seed were dried and stored in paper bags at room temperature until using them for the experiments. In this experiment, we compared the parental body size, seed number and seed weight of the selected species. Plant height, tiller number, seed weight, seed number and the relationship between plant height and seed mass were investigatedunder *Acacia* shade and without *Acacia* shade at both inside and outside enclosure.

Data on the parent body size (height and tiller number), seed number and weight were collected from 40 1 m x 1 m sample plots; 20 sample plots from inside and 20 outside the enclosure. In all cases, the 20 plots were divided into two, i.e., with *Acacia* shade and without. In inside enclosure, 10 sample plots were laid under *Acacia* shade and the other 10 without it. The same sampling method was used for the 20 sample plots located at outside of the enclosure. Plant height was measured and tiller number was counted directly in the field. But seeds were weighed by using Denver instrument, XE-50 digital balance (Max. 50g-Min. 0.0001g).

3.3.3. Sampling methodfor woody and herbaceous at local and landscape level

Two locations [Marmarsa ($9^0$40’20’’N $41^0$49’11’’E) and Shinile Kebeles ($9^0$42’04’’N $41^0$51’38’’E)] were selected for this experiment. A combination of circular and nested plot designs were used to collect data on species diversity at a local scale (defined here as the enclosure) and landscape scale (defined as area 2 km away from the center of the enclosure) – Fig. 2. The radius of the enclosure is 150 m. The total sample plots for each location is 30, i.e., 10 inside the enclosure, 10 at 1 km distance from the center of the enclosure and 10 at 2 km. 20 m x 20 m sample plots were used to collect trees. For shrubs, five 5m x 5 m subplots (four at corners and one at the center of the plot) were laid in each 20 m x 20 m sample plot. A total of 300 sub-plots were used to collect shrub species in both locations. Similarly, five sub-plots of 1 m x 1 m were used for collecting herbs from each 5 m x 5 m sample plots; a total of 300 sub-plots from both locations. Samples from the all plot and subplots were pooled together to find local and landscape level species pool. Species richness (the total number of species) and diversity were determined in the entire location for woody vegetation (tree and shrubs) and herbaceous vegetation (grasses, forbs and weeds).

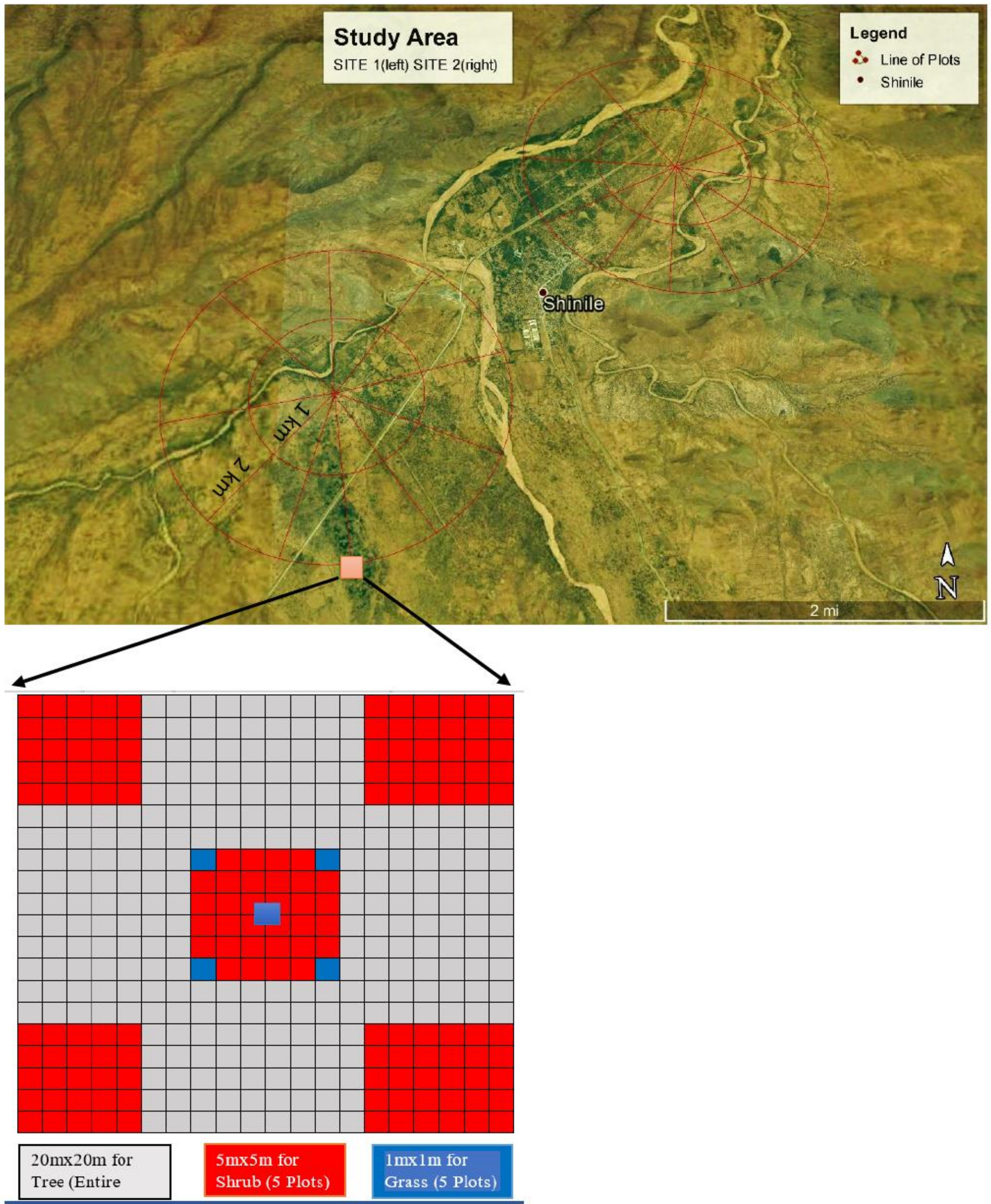


Figure 4: Map of major grazing areas and sampling sites in Marmarsa (left) and Shinile (right) Kebeles and the table shows the sampling procedure for each sampling plot on map.

Data on plant species were collected during the seed bearing period of most of the herbs, grasses and other growth forms, i.e., mid-September 2016. At least two duplicates were collected for each plant sample for identification at the ETH. Where as possible vernacular names of the plants were recorded in the field. The data on species richness of the enclosure were compared with landscape level species pool to understand dispersal capacity of these taxa.

3.3.3.1. Conceptual Framework: Species Pool Definitions

The special framework on local, ecological and regional species pool applied in this part were used by (Jonathan and Walter, 2013).In this study, a species pool is defined as the number of species that are drawn from the two landscapes, i.e., Marmarsa and Shinile Kebeles and species from a combination of sample plots at 1 km and 2 km distances from the center of the enclosure. Table 2 presents the approaches in characterizing the different components of species pool used on figure 4.

Table 2: Description of terms frequently used in the thesis

Term	Location 1 Area (m^2)	Location 2 Area (m^2)	Description
Total species pool	12,566,400	12,566,400	All species found within a 2km radius including all species inside of the enclosure at both locations
Eco-regional species pool	12,502,225	12,484,631	A sub-set of species from total species pool that grows only at 1km and 2km radius from the center of the enclosure
Regional species pool	9,424,800	9,424,800	A sub-set of species from the eco-regional species pool grows only at 2 km radius from the center of the enclosure
Ecological species pool	3,077,425	3,059,831	A set of all species in the region species pool that are bounded within 1 km radius from the center of the enclosure
Local species pool	64,175	81,769	All species found within inside of ten plots at inside of the enclosure.

3.3.4. Data collectionthrough questionnaires and Focal Group Discussion

A semi-structured questionnaire was used for data collection. The questionnaire included both single response from household head and multiple responses from group discussion were designed to assess the perception and indigenous ecological knowledge of pastoralists in rangeland degradation management in Shinile Woreda.The questionnaire was designed to obtain qualitative data on (1) the rangeland degradation indicator, (2) the perception of communities toward rangeland condition, rangeland assessment, rangeland trend, rangeland grass cover, the cause and consequence of rangeland vegetation loss, (3) the perception of pastoralist toward soil degradation, causes for soil degradation, consequence and management practice of soil and (4) understand the status of rangeland enclosure and the contribution of indigenous knowledge of pastoralist to rangeland management.

3.3.4.1. Questionnaire for household

Eight persons with one supervisor, diploma holders and 12th graduates, were trained for data collection. The trainees were oriented for one day to acquire skills for creating conducive environment for the respondents during data collection and clarifying the questions. The questionnaire was pre-tested to understand its robustness and clarity of responses. A total of 200 household, i.e., 50 from Shinile, 50 from Marmarsa, 50 from Harawa and 50 from Hadhkalel Kebeles were randomly selected and interviewed.

3.3.4.2. Focus Group Discussions with selected stakeholder

Focus Group Discussions (FGD) were conducted in each of four Kebeles, to identify rangeland degradation indicators as follows. For the FGD, four groups comprised of elders, community leaders, livestock herders were selected, i.e., 8 from Shinile, 7 from Marmarsa, 7 from Harawa and 9 from Hadhkalel were identified. The discussions were held separately and have focused on the details of the currentrangeland condition such as rangeland degradation indicators and quality of pasture. Rangeland degradation indicators were identified based on a consensus and marked accordingly.

3.4. Statistical analysis

The data collected from the household was analyzed by using SPSS (IBM SPSS Statistics 23, 2015). The frequency and valid percentage were presented using descriptive statistics. Furthermore, focus group discussions with district pastoralexperts, elders, herders and others regarding the study subject were used to get relevantinformation on the indicators to describe rangeland degradation.

The differences in plant species richness, and soil chemical parameters among different sites/plots were analyzed by using variance analysis (ANOVA) of R Software (R version 3.4.1., 2017). Analysis of Variance (ANOVA) is one of the most widely used of statistical techniques and is easily applied using R as an auxiliary and extension to multivariate data analysis. Analysis of variance test was used to compare the means of two or more independent samples. Due to data normalization, to analyze general differences between sites, one way ANOVA was used. Mean value were used to test the richness of grasses and forbs under *Acacia* shade and without it at both enclosed and open grazing areas. Tukey HSD (Tukey Honest Significant Differences) multiple comparison were also used for all statistical tests and significant differences were evaluated at the level of $P \leq 0.05$ for herbaceous species richness, soil nutrient such as soil pH, EC, OC, OM, P, K and seed weight, seed number, plant height and tiller number of selected species at four treatment (IEUA, IEWA, OEUA and OEWA).Correlation coefficients were verified between herbaceous species richness and soil chemical properties. Regression techniques were also used to explain or predict the behavior of a dependent variable. Generally, a regression equation takes the form of $Y=\alpha+\beta x + \varepsilon$, where Y is the dependent variable that the equation tries to predict, X is the independent variable that is being used to predict Y, αis the Y-intercept of the line, and ε is a value called the regression residual.

The impact of enclosure on plant diversity and richness at local, ecological and regional species pool were analyzed by one-way ANOVA.Mean values were tested for grasses, forbs, shrub and woody species richness at local, ecological and regional species pool. Tukey HSD multiple comparison were used to perform multiple comparison of species richness at local, ecological and regional species pool and significant differences for all statistical tests were evaluated at the level of $P \leq 0.05$.

The composition of plant diversity at local, ecological and regional species pools were also calculated using Shannon-Weiner index at separate site individually and total species pool together. It is a measure of the average degree of uncertainty in predicting to what species an individual chosen at random from a collection of species and individuals will belong.

$H' = (N \log N - \sum (n_i \log n_i))/N.$

This equation allows us to compute H' withoutfirst converting abundances (n_i) to proportions (p_i) both saving time and avoiding rounding errors. Sigma plot were also used to drown graph.

Sigma plot were also used to drown graph, table and calculate mean, Y and r^2 valuefor regression graph between species richness and soil chemical properties. It was also used to correlate the regression between plant height and seed weight using scatter plot.

4. RESULTS

4.1. Patch enclosure and localized effects of selected *Acacia* species on herbaceous richness and soil properties

4.1.1. Effect of an enclosure and *Acacia* shade on herbaceous plant species composition

The study shows that both enclosure and *Acacia* shade affects the presence and absence, abundance and number of grasses and herbs of certain species (Table 3). The effects of *Acacia* shade inside the enclosure and outside it (open grazing area) are different as a whole but the magnitudes of these effects are different for different species. Generally, four patterns of the effect of *Acacia* shade have been recorded (Table 3).

1. Species occur under *Acacia* shade and without it inside the enclosure but absent from under *Acacia* shade in the nearby open grazing area. Examples are *Aristida mutabilis*, *Eragrostis manora Ochthochloa compressa* and *Eriochloa nubica.*
2. Species occur under *Acacia* shade and without it inside the enclosure but absent from open grazing area without *Acacia* shade. Examples are *Brachiaria urrata* and *Bergia suffroticosa.*
3. Species occur under *Acacia* shade both inside the enclosure and open grazing area but absent from both areas in open areas. Only one species was recorded in this category, *Chloris gayana.*
4. Species occur under *Acacia* shade and without it inside the enclosures but absent from the nearby open grazing area from both treatments e.g. *Tragus berteronianus.*

A total of 27 plants species were recoded from the different treatments and one of these, *Parthenium hysterophorus,* is an invasive species that was introduced recently. *Eragrostis cilianensis* is the most frequent species while *Tragus berteronianus* and *Eragrostis ciliaris* are the least frequentin the study area (Fig. 5).

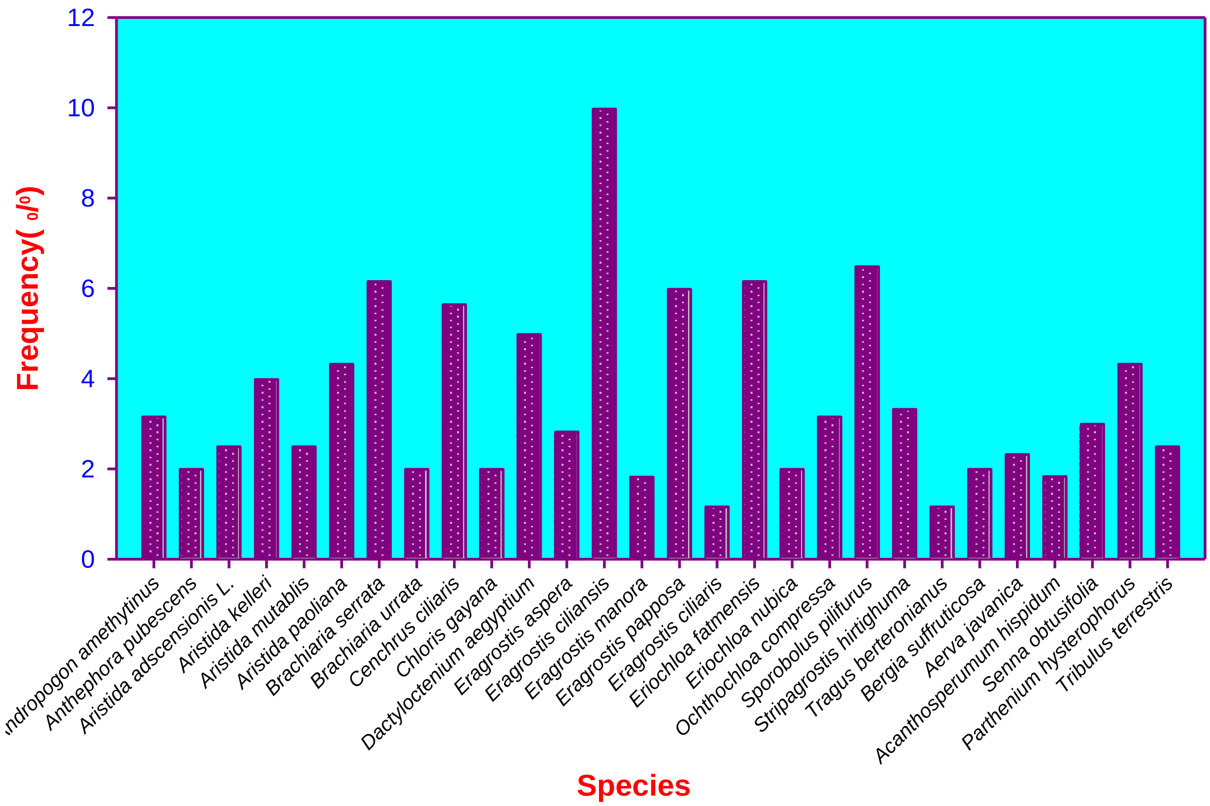


Fig.5: Total species frequency of the study site

Table 3: Mean value ± SD of grasses and forbs/weed and species frequency and their vernacular name of the herbaceous layers at level different enclosure and *Acacia* shade.

	IEUA (N=10)	**IEWA (N=10)**	**OEUA (N=10)**	**OEWA (N=10)**	**Species Frequency (%)**	**Vernacular name**
Grasses	Mean SD	Mean SD	Mean SD	Mean SD		
Andropogon amethytinus	.80±1.03	.40±.52	.60±.70	.10±.32	3.15	Terfae
Anthephora pubescens	.70±.48	.20±.42	.20±.42	.10±.32	1.99	Saard
Aristida adscensionis	.80±.42	.20±.42	.20±.42	.30±.48	2.49	Mayeer
Aristida kelleri	.80±.63	.90±.57	.50±.53	.20±.42	3.98	Duur
Aristida mutablis	.90±.57	.50±.53	0.0±0.00	.10±.32	2.49	Guurta
Aristida paoliana	.80±.42	.60±.52	.60±.52	.60±.52	4.32	Hadaf
Brachiaria serrata	1.5±1.27	.90±.74	.90±.87	.40±.52	6.15	Sardi-cah
Brachiaria urrata	.50±.53	.40±.52	.30±.48	0.0±0.0	1.99	Bael-beleiti
Cenchrus ciliaris	1.30±.82	1.10±.87	.60±.70	.40±.52	5.64	Baldohoor
Chloris gayana	.70±.48	0.0±0.00	.50±.53	0.0±0.0	1.99	Aagaar
Dactyloctenium aegyptium	1.50±.85	1.00±.82	.40±.52	.10±.32	4.98	Maeda-habour
Eragrostis aspera	.60±.69	.70±.82	.30±.48	.10±.32	2.82	Xarfo
Eragrostis cilianensis	2.3±1.16	1.70±.48	1.30±.48	.70±.82	9.97	Harfooe
Eragrostis manora	.60±.52	.30±.48	0.0±0.00	.20±.42	1.82	Saaren
Eragrostis papposa	1.40±.84	1.00±.82	.90±.74	.30±.48	5.98	Mequalihid
Eragrostis ciliaris	.60±.52	.10±.32	0.0±0.00	0.0±0.0	1.16	Nefeer
Eriochloa fatmensis	1.50±.71	.60±.70	.80±.42	.80±.42	6.15	Awis-shebel
Eriochloa nubica	.90±.57	.20±.42	.10±.32	0.0±0.0	1.99	Awis-shebel
Ochthochloa compressa	1.00±.47	.80±.63	0.0±0.00	.20±.42	3.15	Baal-dori
Sporobolus pilifurus	1.80±1.03	1.10±.74	.60±.70	.40±.52	6.48	Yer-yerot
Stripagrostis hirtighuma	1.10±.74	.30±.48	.40±.52	.20±.42	3.32	Osuguul
Tragus berteronianus	.40±.69	.30±.48	0.0±0.0	0.0±0.0	1.16	Merebaabis
Forbs						
Acanthosperumum hispidum	.60±.52	.10±.32	.30±.48	.10±.32	1.83	
Aerva javanica	.50±.53	.30±.48	.50±.53	.10±.32	2.32	Rhido
Bergia suffroticosa	.60±.52	.10±.32	.50±.53	0.0±0.0	1.99	Baareed
Parthenium hysterophorus	.33±.50	1.00±.94	.30±.48	1.00±.47	4.32	Arema cuba
Senna obstusifolia	.90±.57	.20±.42	.60±.52	.10±.32	2.99	Waan-aad
Tribulus terrestris	.40±.51	.50±.52	.40±.51	.20±.42	2.49	Gooundoo

Keys: N= Sampling plots; Inside Enclosure under *Acacia* (IEUA); Inside Enclosure without *Acacia* (IEWA); Outside Enclosure Under *Acacia* (OEUA);Outside Enclosure Without *Acacia* (OEWA)

4.1.2. Effect of enclosures and *Acacia* shade on species richness and soil chemical properties

Our result shows that *Acacia* shade inside enclosures gives protections for recruitment and establishment of grasses and other herbaceous plants. It also affects soil chemical properties.

Generally, both enclosures and *Acacia* shade affect local level plant species richness and soil chemical properties (Table 4). Grass species richness was significantly high under *Acacia* shade (*F*=13.574, *P*=0.*001*) and enclosures (*F*=54.387, *P*=0.000) compared toopen grazing areas. Furthermore, other herbs (forbs/weeds) richness is highly significant under *Acacia* shade than without it *(F=11.243, P=0.002*). On the other hand, species richness in enclosures and open grazing area did not show a significant difference (*F=3.284, P=0.078*).

Table 4: The effects of enclosure and *Acacia* shade on plant species richness and soil chemical properties of the various sites (one-way ANOVA)

	Inside Enclosure vsOutside Enclosure		**Under *Acacia* vs Outside of *Acacia***	
	F	Sig.	F	sig.
Grass	54.387	.000	13.574	.001
Forb	3.284	.078	11.243	.002
pH	24.34	.000	.018	.894
EC (d Sm-1)	.016	.899	150.553	.000
%OC	8.651	.006	69.952	.000
%OM	8.663	.006	70.293	.000
P(ppm)	.198	.659	123.843	.000
K(ppm)	.017	.897	38.116	.000

0.000=highly significant (P<0.05);

The effects of enclosures and *Acacia* shade are completely different (Table 4). All soil chemical properties considered for this study have shown significance difference under *Acacia* shade compared to areas without it. An exception is soil pH which was not affected by the presence or absence of *Acacia* shade *(F=0.018 P=0.894)*.Generally, the difference in soil chemical properties between Acacia shade and without it is high, i.e., there are higher quantities of the soil nutrients under *Acacia* than open areas. On the other hand, areas inside the enclosures and open grazing have displayed different results. The soil pH at inside enclosures and the nearby open grazing areas are significantly different (F=24.34, P=0.000). On the other hand, there is no significant difference in soil chemical properties between enclosures and the nearby open grazing areas (Table 4).

All parameters have shown variations at all sampling sites in terms of species richness and soil chemical properties. For example, the highest mean value was recorded for grasses from inside enclosures under *Acacia* shade and followed by a value from enclosures without it (Table 5). On the other hand, there is a decreasing trend in mean values of grasses from under *Acacia* shade to without it in open grazing areas close to the enclosures. Furthermore, the mean values of EC, OC, P, K and OM were higher under *Acacia* shade of the enclosures and nearby open grazing areas than without it in both treatments (Table 5).

Table 5: Mean values ±SD of the species richness (grasses and forb-weeds) and soil chemical properties of the rangeland at the 40 sampling plots.

	IEUA (N=10)	IEWA (N=10)	OEUA(N=10)	OEWA(N=10)	Average of Mean(N=40)
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
Grasses	23.00±2.87	13.30±3.53	9.20±2.62	5.20±2.097	12.67±7.227
Forbs	3.30±1.42	2.20±1.32	2.60±.84	1.50±.707	2.40±1.25
pH	7.44±.081	7.51±.097	7.06±.42	6.96±.42	7.24±.37
EC(dSm^{-1})	388.10±61.15	226.60±30.92	427.50±67.24	177.70±21.28	304.97±116.54
%OC	1.95±.091	1.23±.18	1.51±.163	1.04±.126	1.43±.372
%OM	3.36±.15	2.13±.31	2.60±.282	1.79±.213	1.43±.372
P(ppm)	34.57±3.66	13.70±7.27	35.59±4.01	16.00±7.318	24.96±11.71
K(ppm)	394.65±50.09	308.31±57.51	417.10±51.92	292.16±58.52	353.05±75.59

Key: N= number of sample plots; electric conductivity (EC), Organic Carbon (OC), Organic matter (OM), Phosphorous (P), Potassium (K); Inside Enclosure under *Acacia* (IEUA), Inside Enclosure without *Acacia* (IEWA), Outside Enclosure Under *Acacia* (OEUA) and Outside Enclosure Without *Acacia* (OEWA).

4.1.3. Relationship between species richness and Soil properties

Soil pH

The soil pH in open grazing areas under *Acacia* shade and without it is slightly acidic and basic (Fig. 6).The study has revealed that soil pH hasshown a positive correlation with species richness in all treatments but with different values of species number (Table 6 and 7; Fig. 6). The species number for both treatments of the open grazing areas fall below the mean species richness except in 1 plot under *Acacia* shade. Inside enclosures, almost 50% of the species richness falls above the mean value for plots samples taken from areas without *Acacia* shade. On the other hand, the species numbers are well above the mean species richness for *Acacia* shade inside enclosures (Fig. 6). Whereas the highest species number was recorded for *Acacia* shade and followed by areas inside enclosures, the lowest number was found for open grazing areas without *Acacia* shade which accounted for 60% of its total species richness.

Table 6: Correlation coefficients of herbaceous species richness and soil chemical properties at IEUA and IEWA

Correlations at IEUA (N=10)							
	Species richness	pH	EC (d Sm-1)	%OC	%OM	P(ppm)	K(ppm)
Species richness	1	.302	.135	.137	.126	-.052	.214
pH	.176	1	-.227	.631	.611	-.564	-.395
EC (d Sm-1)	-.112	.434	1	-.070	-.066	.683*	.450
%OC	.073	-.035	-.240	1	.999**	-.322	-.323
%OM	.074	-.040	-.245	1.000**	1	-.302	-.308
P(ppm)	.168	-.286	-.378	.247	.250	1	.860**
K(ppm)	-.053	.688*	.321	-.287	-.290	-.850**	1
							Correlations at IEWA (N=10)

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). Soil chemical compositions are soil acidity or alkalinity (pH) Electron conductivity (EC), Organic Carbon (OC), Organic matter (OM), soil Phosphorous (P), and potassium (K) in the different categories. The categories are Inside Enclosure under *Acacia* (IEUA), Inside Enclosure without *Acacia* (IEWA).

Electric conductivity (EC)

The higher values of EC were recorded for *Acacia* shade inside enclosures and open grazing areas in all study sites and areas without this shade had lower EC values (Fig. 6). A positive correlation was revealed between species richness and EC only under *Acacia* shade inside enclosures but they are negatively correlated in all treatments. Soil under *Acacia* shade shows highest value of EC and low value of EC was recorded in open grazing areas without *Acacia* shade. Overall, the highest species number under *Acacia* shade inside enclosures and higher EC values are correlated. But *Acacia* shade in open grazing areas has higher EC values but not the highest number of species; the latter falls below the mean species richness. On the other hand, areas without *Acacia* shade inside enclosures have lower EC but the second highest species number with 50% falling above the mean species richness. All open grazing areas in all study sites have exhibited both the lowest species number and EC values (Fig. 6).

Table 7: Correlation coefficients of herbaceous species richness and soil chemical properties at IEUA and IEWA

Correlations at OEUA N=(10)							
	Species richness	pH	EC (d Sm-1)	%OC	%OM	P(ppm)	K(ppm)
Species richness	1	.011	-.485	.003	.010	-.420	-.556
pH	.609	1	.203	-.108	-.105	.168	.189
EC (d Sm-1)	-.451	-.617	1	-.406	-.410	.705*	.908**
%OC	.274	-.044	-.105	1	1.000**	-.453	-.434
%OM	.260	-.062	-.112	1.000**	1	-.461	-.441
P(ppm)	.664*	.431	-.682*	.276	.272	1	.833**
K(ppm)	-.565	-.388	.587	-.137	-.133	-.821**	1
							Correlations at OEWA (N=10)

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). Soil chemical compositions are soil acidity or alkalinity (pH) Electron conductivity (EC), Organic Carbon (OC), Organic matter (OM), soil Phosphorous (P), and potassium (K) in the different categories. The categories are Outside Enclosure under *Acacia* (OEUA) and Outside Enclosure without *Acacia* (OEWA)

Percent Organic Carbon (OC)

Acacia shades inside enclosures have the highest OC value while the lowest was recorded for open grazing area without it. With regard to species number, the highest species number was also recorded for *Acacia* shade inside enclosures (Fig. 6). This is followed by areas without this shade inside enclosures where 40% of their species numbers fall above the mean species richness. The species numbers fall under the mean species richness for open grazing areas with and *Acacia* shade in all study sites.

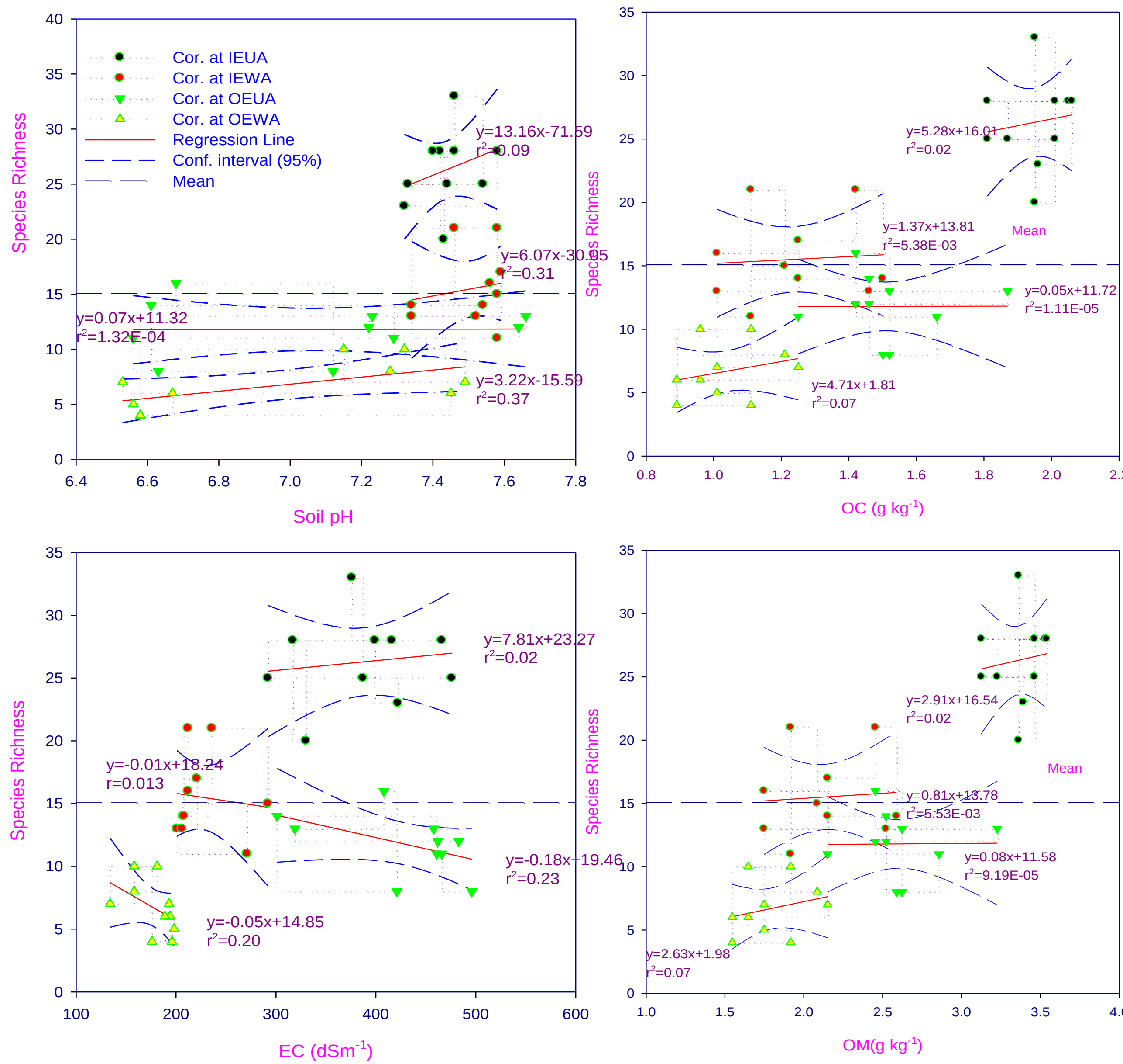


Figure 6: Relationship between species richness and soil pH, EC, OC and OM at IEUA, IEWA, OEUA and OEWA

Percent of Organic Matter (OM)

Analyses of the relationships of OM and species richness revealed similar to that of OC and species richness. Whereas *Acacia* shade inside enclosures has the highest OM values and species number, open grazing areas without it revealed the least OM value and species number. Except for areas inside enclosures without *Acacia* shade, both open grazing areas with and without *Acacia* shade have species number below the mean species richness.

Phosphorus (P)

Our result shows that enclosures did not improve Phosphorus content unless coupled with *Acacia* shade (Table 6 and 7; Fig. 7). But open grazing areas with this shade did not show higher species number. Instead their species numbers fall below the mean species richness. However, Phosphorus content is higher than areas without the shade inside enclosures and open grazing areas. The highest species number and Phosphorus content were recorded for *Acacia* shade inside enclosures. On the other hand, the lowest was found in open grazing areas without *Acacia* shade. The second highest species number was recorded for areas inside enclosures but without the canopy.

Potassium (K)

The content of Potassium was found to be variable with wide ranges across the different sites of this study (Table 5 and 7; Fig. 7). *Acacia* shade inside enclosures and open grazing areas have shown relatively higher Potassium content but not concurrently higher number of species. In open grazing areas, *Acacia* shade has revealed lower species number falling under the mean species richness in all study sites. Furthermore, the lowest species number was recorded for open grazing areas without the shade of *Acacia*. The second highest species number was recorded for areas inside enclosures without *Acacia* shade.

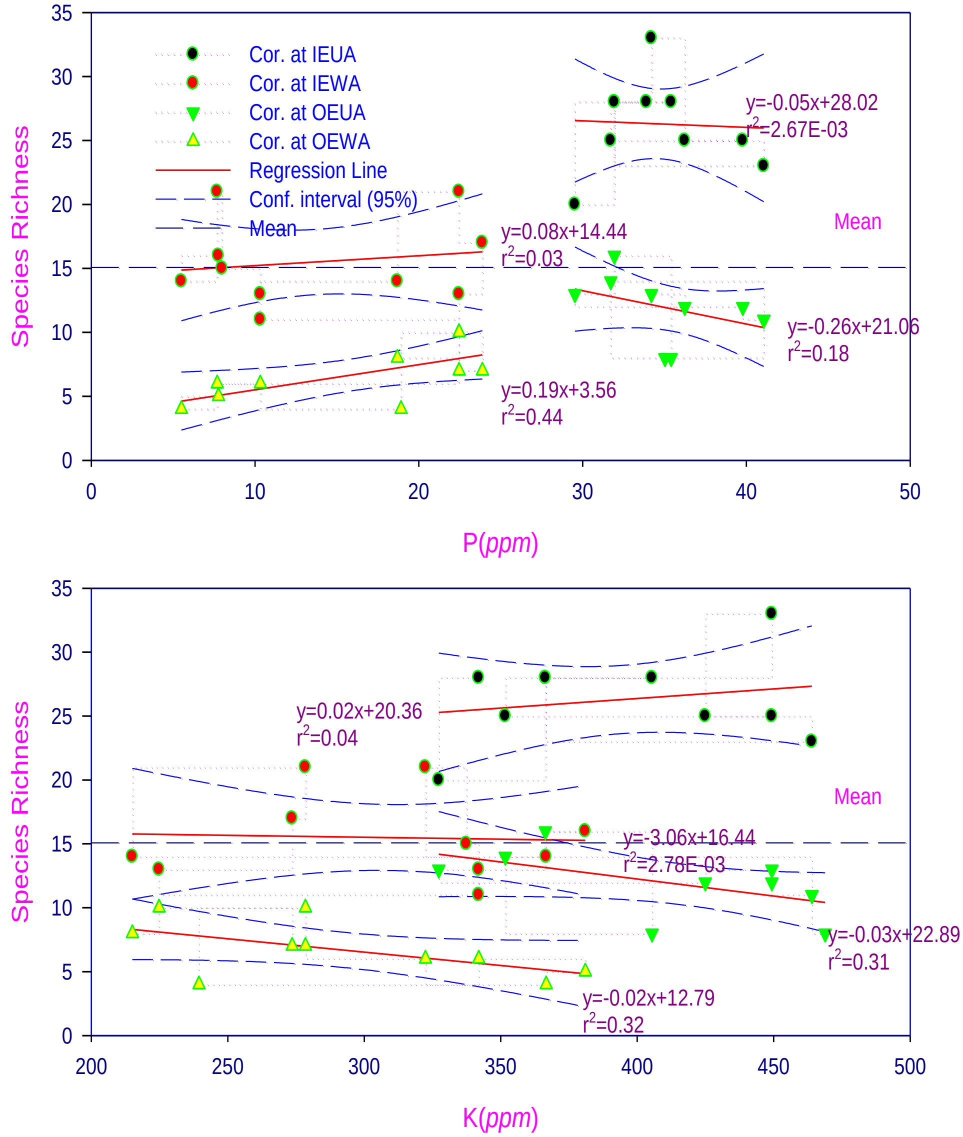


Figure 7: Relationship between species richness with P and K at IEUA, IEWA, OEUA and OEWA

4.2. The effect of enclosure and *Acacia* shade on phenotypic plasticity of some maternal traits of selected grasses

4.2.1. Local environmental factors modulate maternal traits

Four parameters were analyzed in connection to maternal traits (Fig. 6 and Appendix A3). These are height, tiller number, seed weight and seed number.

Height

Our results show that both enclosure and *Acacia* shade can substantially improves plant height, tiller number, seed number and seed weight of *Aristida kelleri, Eragrostis cilianensis, Cenchrus ciliaris, Eriochloa fatmensis, Dactyloctenium aegyptium* and *Tragus berteronianus*(Fig. 6).*Aristida kelleri, Cenchrus ciliaris, Eriochloa fatmensis, Dactyloctenium aegyptium* and *Tragus berteronianus*grow longer under *Acacia* shade inside enclosures and open grazing areas than areas without the shade in both treatments. On the other hand *Eragrostis cilianensis* has shown higher height under *Acacia* shade inside enclosures, less so in areas without shade inside enclosures and *Acacia* shade in open grazing areas (Fig. 6). But this species is growing short and stunted in open grazing areas without *Acacia* shade.

Tiller number

Our results show that the responses of plants to the four treatments are variables for different species. Generally, tiller numbers tend to increase inside enclosures with and without *Acacia* shade (Fig. 6). On the other hand, *Aristida kelleri*has exhibited the highest number of tiller (about 5 per plant) growing under *Acacia* shade in open grazing areas in all study sites. The number of tiller is less than 4 per plant in the remaining treatments of this experiment. For *Cenchrus ciliaris*, relatively higher number of tiller (> 4 per plant) was recorded for both treatments inside enclosures and it is much lower (< 3 per plant) in open grazing areas with and without *Acacia* shades. A similar pattern was also recorded for *Tragus berteronianus*and*Dactyloctenium aegyptium*. Tiller number has remained has slightly changed under the different treatments for *Eragrostis cilianensis* (Fig. 6). In *Eriochloa fatmensis*, the number of tillers per plant has declined in areas without *Acacia* shade in open grazing areas but increased in the remaining treatments.

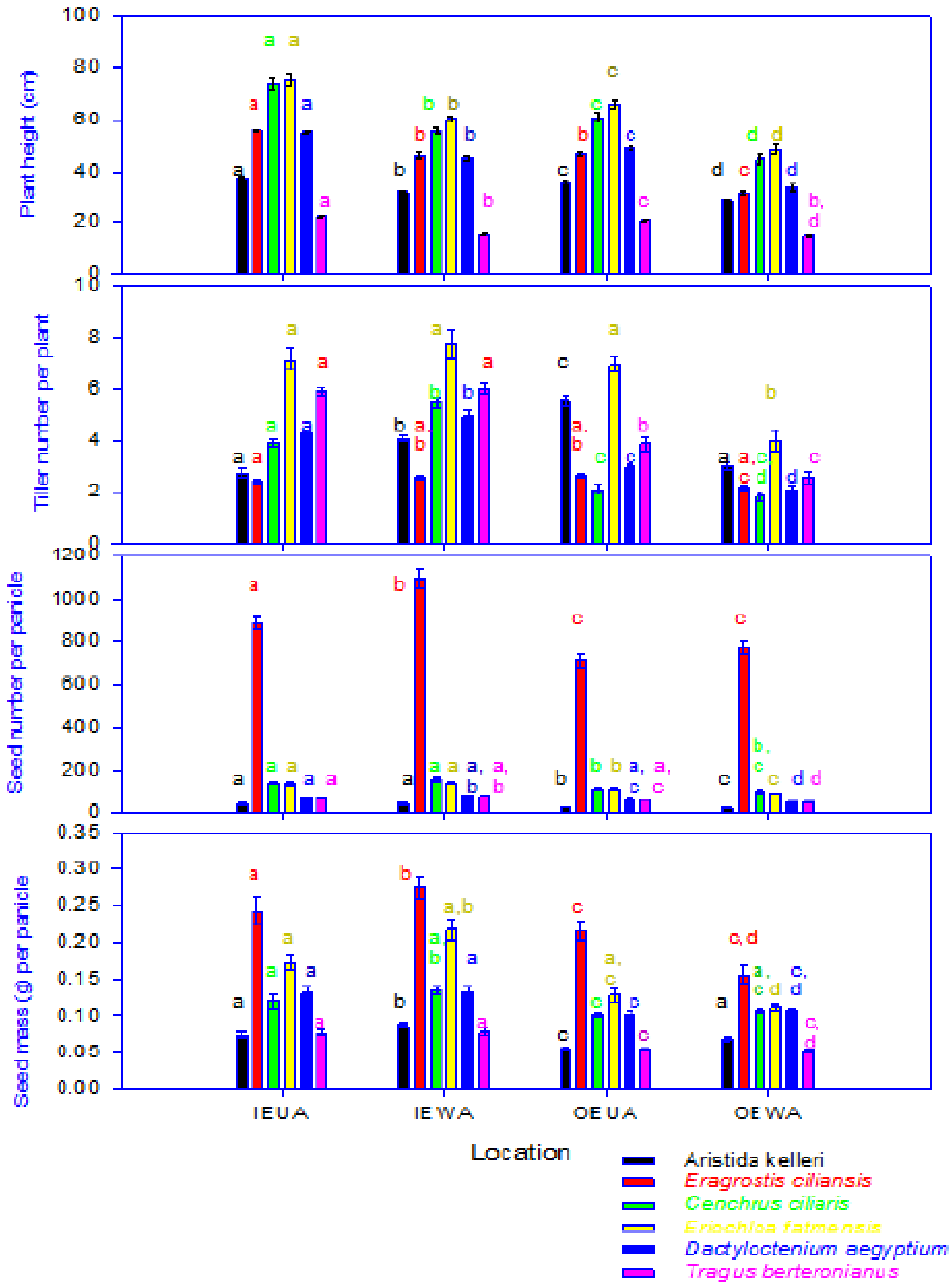


Figure 6: Value of plant height, tiller number, seed number and seed weight of selected species at IEUA, IEWA, OEUA and OEWA (This figure is illustrated numerically on Appendix A3)

4.2.2. Plant vigor determines seed weight and number

Seed number

Seed numbers were counted per inflorescences of the selected plant species (Fig. 6). The responses of the plants to the four treatments are different. Some species tend to have higher seed number per inflorescence inside enclosures and less in open grazing areas. For example, the number of seeds of *Eragrostis cilianensis*is higher inside enclosures than open grazes areas. Whereas higher numbers of seeds are recorded for *Acacia* shade inside enclosures for this species, areas without the shade in open grazing areas have relatively higher seed number in all study sites. For the remaining species, seed number remains comparable with a declining tendency for areas without Acacia shade in open grazing areas.

Seed weight

The seed weight was also measured per inflorescences for each species (Fig. 6). All the selected species have shown higher seed weight inside enclosures than in open grazing areas. Although seed weight from open grazing with *Acacia* shade is smaller than the two treatments inside enclosures, it is significantly higher than areas without it in open grazing areas. In some species, e.g. *Tragus berteronianus* and *Cenchrus ciliaris*, seed weight was not different in the respective treatments of inside enclosures and open grazing areas (Fig. 6).

4.2.3. Relationship between plant height andseed mass

Three patterns have emerged when correlation analyses were conducted for plant height and seed weight (Fig. 7). A negative correlation of plant height to seed weight in *Aristida kelleri* (R^2=0.027) but it is not statistically significant (P=0.313). Furthermore, plant height of *Cenchrus ciliaris*is slightly correlated to seed weight (R^2=1.07E-03, P=0.841). A positive correlation was recorded for *Eragrostis cilianensis* and *Tragus berteronianus*and the correlation was not significant, i.e., R^2=0.082 and R^2=0.024, respectively (Fig. 7). On the other hand, a significant correlation between plant height and seed weight was recorded for *Eriochloa fatmensis* (R^2=0.170, P=0.008) and *Dactyloctenium aegyptium* (R^2=0.123, P=0.027).

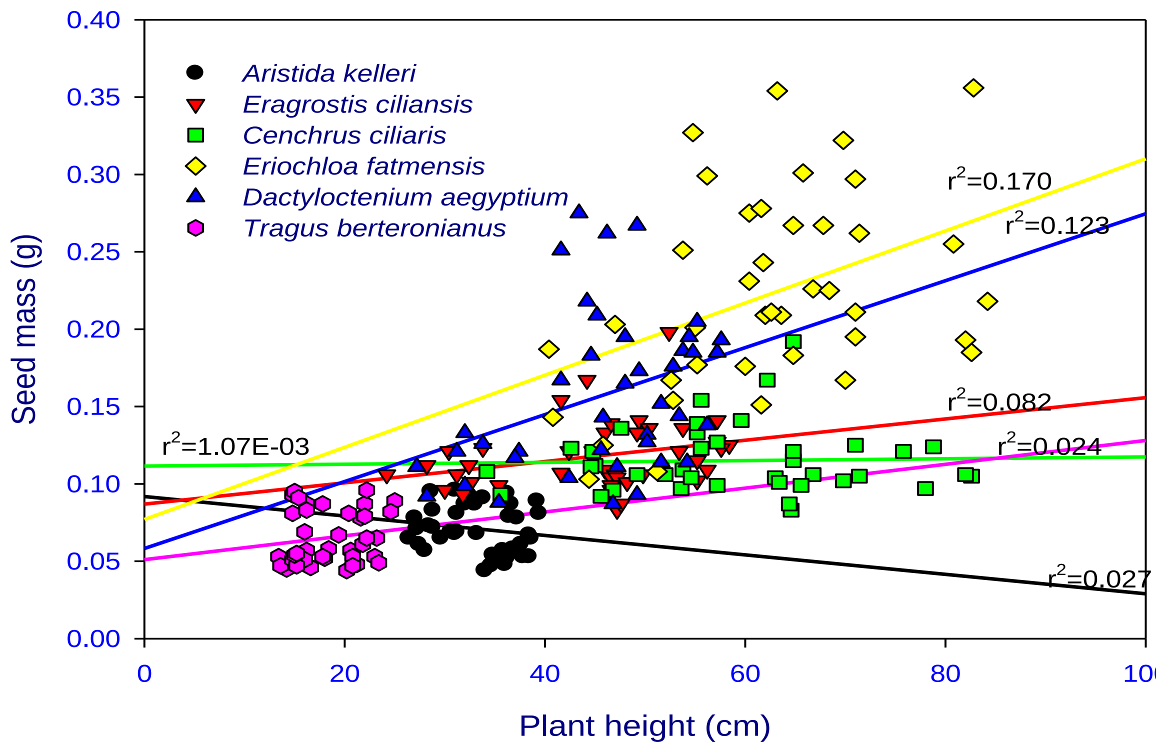


Figure 7: The relationship between plant height (cm) and wing loading seed mass for the six different grass species. R^2 and p-value (P) is shown for each species

4.2.4. Analyses of maternal traits of selected grass species

Aristida kelleri

Our results show that enclosures and *Acacia* shade affect maternal traits such as height, tiller number, seed number and weight (Table 8). In *Aristida kelleri*, plant height has shown a slight increase inside enclosures compared to nearby open grazing areas but statistically not significant (F=3.836, P=0.058). The height of the same species has significantly increased under *Acacia* shade (F=112.316, P=0.000; Table 8). In contrast of all selected grasses, there was more tiller number for plants of this species growing in open grazing areas than inside enclosures (F=5.642, P=0.023). However, Tiller number of *Aristida kelleri* was not affected by *Acacia* shade (F=2.430 P=0.127). Whereas seed number of this species was significantly higher inside enclosures (F=121.701, P=0.000), it did not show significant difference with or without *Acacia* shades in the study area (F=0.325, p=0.572). With regard to seed weight, both enclosures (F=30.224, P=0.000) and *Acacia* shade (F=8.941, P=0.005) revealed higher values in the study area.

Eragrostis cilianensis

Plant height has significantly increased inside enclosures (F=28.502, P=0.000) and under *Acacia* shade (F=33.817, P=0.000; Table 8) in all study site. On the other hand, enclosures (F=5.642, P=0.410) and *Acacia* shade (F=2.430, P=.127) did not have effect on tiller number of this species. Whereas seed number has significantly increased inside enclosures (F=37.862, P=0.000), its decreased under *Acacia* shade in all study sites was significant (F=6.523, P=0.015). Although seed weight has significantly increased inside enclosures (F=20.886, P=0.000), it has remained unchanged in *Acacia* shades at all sites (Table 8).

Cenchrus ciliaris

Plant height has significantly increased inside enclosures (F=12.110, P=0.001), *Acacia* shade (F=42.939, P=0.000) but tiller number of this species had revealed a significant increase only in enclosures (F=113.582, P=0.000). *Acacia* shade has negatively affected tiller number of *Cenchrus ciliaris* (Table 8). Both seed number and weight have revealed significant variations inside enclosures but the differences were not significant for both traits in *Acacia* shade (Table 8) in all study sites.

Eriochloa fatmensis

The height of this species has increased inside enclosures (F=11.271, P=0.002) and *Acacia* shade (F=43.880, P=0.000) significantly in all study sites (Table 8). *Acacia* shade has not effect on tiller number and it has increased significantly inside enclosures (Table 8). Whereas *Acacia* shade did not have effect on seed number and weight, enclosures have revealed an increase in both maternal traits.

Dactyloctenium aegyptium

Enclosures have significantly affected height and tiller numbers of this species in all study sites (Table 8). On the other hand, the responses of *Dactyloctenium aegyptium* to *Acacia* shade with regard to these maternal traits are different, i.e., shade increased height significantly (F=54.167, P=0.000) but did not have effect on tiller number. Although seed number and weight have significantly increased inside enclosures, the presence or absence of *Acacia* shade did not reveal significant differences (Table 8)

Tragus berteronianus

Enclosures and *Acacia* shades present opposing effects on height and tiller number of *Tragus berteronianus* in all study sites (Table 8). The effect of *Acacia* shade on height of this species is significant (F=157.080, P=0.000) but did not show significant variations for tiller numbers. On the other hand, enclosures has increased tiller number significantly (F=111.845, P=0.000) but did not show significant differences for height. Whereas there is not significant variations in seed number and weight for *Acacia* shade in all study sites, enclosures have significantly increased the values of these maternal traits (Table 8).

Table 8: The effects of enclosure and *Acacia* shade on plant species richness and soil chemical properties of the various sites (one-way ANOVA)

	Inside Enclosure*Outside Enclosure								Under *Acacia**Outside of *Acacia*							
	Plant height		**Tiller number**		**Seed number**		**Seed weight**		**Plant height**		**Tiller number**		**Seed number**		**Seed weight**	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Aristida kelleri	3.836	.058	5.642	.023	121.701	.000	30.224	.000	112.316	.000	2.430	.127	.325	.572	8.941	.005
Eragrostis cilianensis	28.502	.000	.694	.410	37.862	.000	20.886	.000	33.817	.000	1.991	.166	6.523	.015	.246	.623
Cenchrus ciliaris	12.110	.001	113.582	.000	35.943	.000	15.485	.000	42.939	.000	1.754	.193	.023	.880	2.167	.149
Eriochloa fatmensis	11.271	.002	13.251	.001	45.582	.000	19.024	.000	43.880	.000	3.900	.056	1.017	.320	.491	.488
Dactyloctenium aegyptium	14.399	.001	122.702	.000	30.916	.000	45.177	.000	54.167	.000	.082	.776	.174	.679	.757	.390
Tragus berteronianus	1.115	.298	111.845	.000	32.543	.000	55.094	.000	157.080	.000	1.352	.252	.499	.484	.012	.913

4.3. Impacts of enclosures on plant diversity and richness: local and regional species pool perspectives

4.3.1. Floristic composition

A total of 39 different herbaceous and 36 woody species were recorded in the study sites (Table 9 and 10). Thirty one species of the herbaceous plants are grasses while 8 are non-grass herbs. The woody species are trees (15 species), shrubs (9) and shrub or tree (11) following the Flora of Ethiopia and Eritrea.

Table 9: Herbaceous species abundance at local species pool (inside enclosure), ecological species pool (1km) and regional species pool (at 2km) as well as their vernacular name and family name of herbaceous plant at site 1 and site 2

Grasses		**Herbaceous species Abundance**						**Vernacular name**	**Family name**
		Site 1			**Site 2**				
		IE	1km	2km	IE	1km	2km		
1	*Andropogon amethytinus*	30	17	16	29	18	9	Terfae	Poaceae
2	*Andropogon sorghum*	14	6	6	18	10	11	Terfae	Poaceae
3	*Anthephora pubescens*	25	17	20	31	21	14	Saard	Poaceae
4	*Aristida adscensionis*	36	18	14	33	16	13	Mayeer	Poaceae
5	*Aristida kelleri*	29	18	5	20	15	14	Duur	Poaceae
6	*Aristida mutablis*	29	12	15	26	6	8	Guurta	Poaceae
7	*Aristida paoliana*	26	15	15	27	8	7	Hadaf	Poaceae
8	*Brachiaria serrata*	25	14	20	24	16	13	Sardi-cah	Poaceae
9	*Brachiaria urrata*	21	11	17	24	8	6	Bael-beleiti	Poaceae
10	*Cenchrus ciliaris*	39	24	26	37	21	26	Baldohoor	Poaceae
11	*Chloris gayana*	25	8	5	20	8	5	Aagaar	Poaceae
12	*Dactyloctenium aegyptium*	21	16	17	20	15	15	Maeda-habour	Poaceae
13	*Echinochloa crus-galli*	28	15	4	29	15	6	Osuguul	Poaceae
14	*Eragrostis aspera*	18	17	16	23	16	18	Xarfo	Poaceae
15	*Eragrostis cilianensis*	70	30	31	69	32	33	Harfooe	Poaceae
16	*Eragrostis manora*	44	26	25	42	26	19	Saaren	Poaceae
17	*Eragrostis papposa*	27	5	16	24	15	8	Mequalihid	Poaceae
18	*Eragrostis ciliaris*	9	4	5	12	8	4	Nefeer	Poaceae
19	*Eriochloa fatmensis*	17	18	6	20	16	9	Awis-shebel	Poaceae
20	*Eriochloa nubica*	21	4	4	22	6	4	Awis-shebel	Poaceae
21	*Frimbristylis keniacensis*	20	14	11	22	13	11	Saard	Cyperaceae
22	*Hyparrhenia hirta*	20	16	5	21	16	12	Hadaf	Poaceae
23	*Hypheana thebaica*	19	4	4	10	6	8	Gouoon	Arecaceae
24	*Leptochloa obtusiflora*	17	7	5	17	7	7	Raari-feres	Poaceae
25	*Ochthochloa compressa*	29	6	4	31	6	7	Baal-dori	Poaceae
26	*Panicum coloratum*	23	14	14	20	8	5	Daerdi	Poaceae
27	*Sorghum arundinaceum*	22	16	13	29	15	10	Mequalihdae	Poaceae
28	*Sporobolus pilifurus*	31	13	5	33	11	14	Yer-yerot	Poaceae

29	*Stripagrostis hirtighuma*	25	17	13	26	16	13	Osuguul	Poaceae
30	*Tetrapogon cenchriformis*	17	14	14	17	7	8	Haarfo	Poaceae
31	*Tragus berteronianus*	15	10	4	13	5	17	Merebaabis	Poaceae
	Forbs								
32	*Acanthosperumum hispidum*	24	13	10	26	7	7	Wani-aad	Asteraceae
33	*Aerva javanica*	21	15	13	27	9	19	Rhido	Amaranthaceae
34	*Bergia suffroticosa*	24	12	17	24	14	8	Kallinole	Rosaceae
35	*Parthenium hysterophorus*	37	42	39	37	41	34	Arema cuba	Parthenium
36	*Senna obstusifolia*	16	19	13	14	11	11	Waan-aad	Caesalpiniaceae
37	*Solanum carolinense*	29	16	12	23	13	15	Kirrir	Solanaceae
38	*Tribulus terrestris*	19	11	4	26	7	5	Goounde	Zygophylaceae
39	*Xanthium strumarium*	27	6	3	18	13	13	Oufi	Asteraceae

4.3.2. Enclosures increases herbaceous species richness

Herbaceous species richness has increased due to enclosures at local levels but dramatically decreased at a landscape scale in all study sites. There are exceptions to this general trend. Some species, for example, such as *Cenchrus ciliaris, Artstida kelleri, Eragrostis cilianensis, Tragus berteronianu*s and *Aerva javanica*tend to be more abundance at 2 km away from the center of enclosuresin site 2. The same trend was also observed for *Bergia suffroticosa, Eragrostis papposa* and *Anthephora pubescens* in site 1 (Table 9). On the other hand, there was no species turn over as a function of distance from enclosures. The most abundant grass is *Eragrostis cilianensis*in all study sites (Table 9).

4.3.3. Enclosures reduced woody species richness

The impacts of enclosures are different for woody species (Table 10). The abundance of woody species decreases in enclosures but increases away from then across the landscape in all study sites (Table 10). For example, *Acacia bussei*, *Acacia Senegal, Aloe somaliensis, Aloe tricosantha, Boswellia sacra, Cadaba farinosa, Commiphora abyssinica, Dichrostachys cinerea, Euphorbia abyssinica, Salvadora persica, Senna alexandrina*and *Tamarindus indica*are very common in the landscape away from the enclosures in the study areas (Table 10). The invasive *Lantana camara* is common in the landscape but absent in the enclosures. Similarly, *Prosopis juliflora* occurs far from the enclosures and was found to be the most abundant plant species. On the other hand, some species, e.g. *Balanites aegyptica* and *Cadaba glandolosa* were found in enclosures but in a very small number. Other species were found inside enclosures but completely absent in the landscape (Table 10). Generally, enclosures have variously affected woody species abundance at a local and landscape scales.

Table 10: Woody species abundance at local species pool (inside enclosure), ecological species pool (1km) and regional species pool (at 2km) as well as their life form, vernacular name and family name of woody plant at site 1 and site 2

No	Species name	Woody species abundance						Life Form	Vernacular (Somali name)	Family name
		Site 1			Site 2					
		IE	1km	2km	IE	1km	2km			
1	*Acacia albida*	3	6	0	3	6	5	T	Garbi	Mimosaceae
2	*Acacia asak*	9	19	20	0	20	16	SH/T	Adad-medu	Mimosaceae
3	*Acacia bussei*	0	6	5	0	6	3	T	Galool	Mimosaceae
4	*Acacia mellifera*	2	19	19	8	20	16	SH/T	Beei-iegn	Mimosaceae
5	*Acacia nilotica*	11	19	18	10	17	16	SH/T	Maara	Mimosaceae
6	*Acacia nubica*	8	13	13	13	18	13	SH	Gumero	Mimosaceae
7	*Acacia Senegal*	0	14	18	10	22	18	SH/T	Adad-meru	Mimosaceae
8	*Acacia tortilis*	3	5	6	4	4	3	T	Abak	Mimosacea
9	*Aloe somaliensis*	0	5	0	0	0	0	SH	Da-aar	Liliaceae
10	*Aloe tricosantha*	0	4	4	0	4	0	SH	Daar-maroodi	Liliaceae
11	*Azadirachta indica*	3	2	0	2	4	0	T	Kininzaf	Meliaceae
12	*Balanites aegyptiaca*	2	4	3	1	2	2	T	Got	Balanitaceae
13	*Balanites galabra*	2	4	4	2	2	3	T	Kiddi	Balanitaceae
14	*Boswellia sacra*	0	4	0	1	5	0	T	Mohor	Burseraceae
15	*Cactus ficus-indica*	0	8	10	0	9	6	SH	Gueruus	Calcataceae
16	*Cadaba farinosa*	0	10	9	0	0	10	SH	Dita-aab	Capparaceae
17	*Cadaba glandulosa*	2	2	12	0	7	13	SH	Queleen	Capparaceae
18	*Calotropis procera*	0	10	0	0	0	5	SH	*Boha*	Apocynaceae
19	*Commiphora abyssinica*	0	0	10	0	12	12	SH/T	Aeeqaad	Burseraceae
20	*Delonix regia*	2	4	0	2	3	0	T	Direzaf	Fabaceae
21	*Dichrostachys cinerea*	0	13	13	0	11	0	SH/T	Dhigdar	Fabaceae
22	*Dobera glabra*	4	0	0	0	0	0	SH/T	Garas	Salvadoraceae
23	*Euphorbia abyssinica*	0	2	2	0	0	2	T	Haadaan	Euphorbiaceae
24	*Euphorbia tirucalli*	2	2	2	1	3	2	T	Dharkeyn	Euphorbiaceae
25	*Grewia bicolor*	6	18	17	0	12	13	SH/T	Kobesh	Tiliaceae
26	*Grewia ferruginea*	6	9	11	0	8	11	SH/T	Lato	Tiliaceae
27	*Lantana camara*	0	16	15	2	11	15	SH	Laawo	Verbenaceae
28	*Melia azedarach*	2	0	0	0	0	0	T	Melia	Meliaceae
29	*Moringa oleifera*	4	5	4	3	5	0	T	Moringa	Moringaceae
30	*Prosopis juliflora*	17	36	31	20	39	33	SH/T	Damal	Fabaceae
31	*Salvadora persica*	0	18	0	5	10	0	SH/T	Aadey	Salvadoraceae
32	*Senna alexandrina*	0	11	8	0	9	10	SH	Jelalo-jel	Fabaceae
34	*Tamarindus indica*	0	3	0	0	0	0	T	Raqay	Fabaceae
35	*Ziziphus mauritiania*	2	6	4	2	3	3	T	Gobyar	Rhamnaceae
36	*Ziziphus mucronata*	2	4	4	1	0	3	T	Edi-shabeel	Rhamnaceae

4.3.4. Species diversity

The result of Shannon-Weiner diversity indexshowed low value at inside enclosurecompared with the outside location circulate around enclosure within radius of 1km and 2km for both study site, i.e., it showed that local species pool were lower in plant diversity than both ecological and regional species pool at both study site (Table 11).

Table 11: Diversity of individual and total plant species by Shannon-Weiner diversity index

	Shannon-Weiner diversity index (H')	
Scales	Site 1	Site 2
Inside enclosures	1.66	1.66
1 km from the centers	1.82	1.78
2 km from centers	1.77	1.87

4.3.5. Herbaceous and woody species composition

The mean value of grass species richness at local species pool showed significant difference with the two ecological and regional species pool circulate around enclosure within radius of 1km and 2km in communal grazing site (Table 12 and 13). Accordingly, the grass mean values counted at local species pool (15.84±0.75) were significantly higher than grass mean value at ecological species pool (8.74±0.72) and regional species pool (7.50±0.75), (P=0.000 with 1km, P=0.000 with 2km). Similarly for site two, significantly high grass mean value were recorded at local species pool (15.58±0.80) than at 1km (8.12±0.72) and 2km (7.20±0.75) distance round the enclosure (P=0.000 with 1km, P=0.00 with 2km). Then again ecological species pool and regional species pool did not show significant difference (P=0.240) for site one and (P=0.392) for site two in the midst of each other. Both sites were displaying relatively normal distributions of grass species at two radiuses. This indicates that inside enclosures sites had substantially many grass species composition than outside communal grazing site, but the two radiuses at outside of enclosure were almost comparable to each other. The reason behind the low grass species composition at communal grazing site circulates around enclosure might be primarily due to the high livestock grazing pressure on rangelands.

In both study sites, forb mean value at local species pool also shows great difference with the ecological and regional species pool (Table 12 and 13). As the result, for site one, forb mean value at local species pool (3.94±0.27) were significantly higher than forb mean value recorded at ecological species pool (2.68±0.19) and regional species pool (2.22±0.21) (P=0.000 with 1km, P=0.000 with 2km). Similarly, at site two, significant forb mean value were recorded at local species pool (3.90±0.21) compared with forb mean value at ecological species pool (2.30±0.21) and regional species pool (2.24±0.27) (P=0.000 with 1km, P=0.000 with 2km). Howeverforb composition at ecological and regional species pool did not show significant difference (P=0.153) for site one and (P=0.857) for site two between each other. Generally herbaceous species diversity was protected by enclosure, which is considered as local species pool. This indicates that local species poolhad substantially high herbaceous composition than eco-regional species pool

Table 12: Mean ± SE of grasses, forbs/weed shrub and tree of site one and site two at local, ecological and regional species pool

				SITE 1	**SITE 2**
		Plot number (N)	Plot size (m^2)	Mean SE	Mean SE
GRASS	Local species pool (Inside enclosure)	50	1x1	15.84±0.75	15.58±0.80
	Ecological species pool (at 1km)	50	1x1	8.74±0.72	8.12±0.72
	Regional species pool (at 2km)	50	1x1	7.50±0.75	7.20±0.75
	Total	150		10.69±0.52	10.30±0.53
FORB	Local species pool (Inside enclosure)	50	1x1	3.94±0.27	3.90±0.21
	Ecological species pool (at 1km)	50	1x1	2.68±0.19	2.30±0.21
	Regional species pool (at 2km)	50	1x1	2.22±0.21	2.24±0.27
	Total	150		2.95±0.14	2.81±0.15
SHRUB	Local species pool (Inside enclosure)	50	5x5	0.94±0.14	0.98±0.12
	Ecological species pool (at 1km)	50	5x5	3.98±0.31	3.72±0.49
	Regional species pool (at 2km)	50	5x5	3.70±0.52	3.62±0.42
	Total	150		2.87±0.23	2.77±0.24

TREE	Local species pool (Inside enclosure)	10	20x20	4.50±0.69	4.10±0.59
	Ecological species pool (at 1km)	10	20x20	10.20±2.84	8.60±2.65
	Regional species pool (at 2km)	10	20x20	7.70±2.83	5.70±2.21
	Total	30		7.47±2.38	6.13±1.18

However, in both sites lower shrub mean values were recorded at local species pool compared with ecological and regional species pool (Table 12 and 13). Local species pool had significantly lower shrub mean value (0.94±0.14) than two outside sampling site circulating at 1km (3.98±0.31) and 2km (3.70±0.52) radius (P=0.000 with 1km, P=0.000 with 2km)for site one. Similarly shrub mean value at local species pool (0.98±0.12) were significantly lower than shrub mean values at ecological species pool(3.72±0.49) and regional species pool (3.62±0.42) (P=0.000 with 1km, P=0.000 with 2km) for site two. Still, at outside communal grazing land, site one displayed similar distribution of forb mean value between ecological and regional species pool (P=0.581). Also site two shows similar value of forb mean value at ecological and regional species pool (P=0.854). This means, there was no significant difference among the outside site at both study site. This indicates that eco-regional species pool had substantially high shrub composition than local species pool.

In both study sites, slight low mean value of the tree vegetation were found at local species pool compared with eco-regional species pool (Table 12 and 13). Accordingly, low but not significant tree mean value were recorded at local species pool (4.50±0.69) compared with tree mean value at ecological species pool (10.20±2.84) and regional species pool (7.70±2.83) (P=0.098 with 1km, P=0.344 with 2km) for site one. Also for site two slightly low but not significant tree mean value were recorded at local specie pool (4.10±0.59) compared with tree mean value at ecological species pool (8.60±2.65) and regional species pool (5.70±2.21) (P=0.128 with 1km, P=0.581 with 2km). However, at outside communal grazing land both site did not show significant difference between ecological and regional species pool circulate around the local species pool (Table 12 and 13).

Table 13: The significance difference of plant species richness among IE (local species pool), 1km (Ecological species pool) and 2km (regional species pool) at both study area

			SITE 1		SITE 2	
DEPENDENT VARIABLE	I	J	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.
GRASS (N=50)	IE	1km	7.10000*	.000	7.46000*	.000
		2km	8.34000*	.000	8.38000*	.000
	1km	IE	-7.10000*	.000	-7.46000*	.000
		2km	1.24000	.240	0.92000	.392
	2km	IE	-8.34000*	.000	-8.38000*	.000
		1km	-1.24000	.240	-0.92000	.392
FORB (N=50)	IE	1km	1.26000*	.000	1.60000*	.000
		2km	1.72000*	.000	1.66000*	.000
	1km	IE	-1.26000*	.000	-1.60000*	.000
		2km	0.46000	.153	.06000	.857
	2km	IE	-1.72000*	.000	-1.66000*	.000
		1km	-0.46000	.153	-.06000	.857
SHRUB (N=50)	IE	2.00	-3.04000*	.000	-2.74000*	.000
		2km	-2.76000*	.000	-2.64000*	.000
	1km	IE	3.04000*	.000	2.74000*	.000
		2km	0.28000	.581	.10000	.854
	2km	IE	2.76000*	.000	2.64000*	.000
		1km	-0.28000	.581	-.10000	.854
TREE (N=10)	IE	1km	-5.70000	.098	-4.50000	.128
		2km	-3.20000	.344	-1.60000	.581
	1km	IE	5.70000	.098	4.50000	.128
		2km	2.50000	.459	2.90000	.320
	2km	IE	3.20000	.344	1.60000	.581
		1km	-2.50000	.459	-2.90000	.320

0.000=highly significant ($P<0.05$);

Generally, different range condition was observed in enclosure and communal grazing areas for grasses, forbs, shrub and trees. Overall results showed that grazing pressure and human interference were significantly altered total vegetation cover of the rangeland. Higher grass and forb composition were recorded inside enclosure than outside communal grazing site. However, the variation in total shrub and tree vegetation cover registered at inside of enclosure reduced significantly compared with outside. Herbaceous vegetation cover increased significantly at local species pool. In contrast woody vegetation covers (especially shrub) were significantly reduced at local species pool.

4.4. Assessment of perception and indigenous knowledge of pastoralists

4.3.6. Rangeland degradation indicators

Communities in the study areas are aware of the extent of rangeland degradation using their local indicators. Based on participatory research approach (Hay, 2010), integration with the indigenous knowledge of pastoralist, sixteen (16) degradation indicators were identified (Table 14). Pastoral communities have identified numerous indicators to describe rangeland degradationsuch as vegetation indicators, soil (edaphic) indicators and indicators related to different aspects of rangelands and community in addition to vegetation and soil.

Shinile Kebele pastoralist's use all indicators, i.e., vegetation, soil and others, for assessing rangeland degradation. Therefore, they focus on all indicators and give no preference of one to the others. Except for an increase in annual plants (growth form) as indicator, pastoral communities from Marmarsa Kebele use all other indicators to evaluate rangeland degradation. Pastoral communities from both Kebeles focus on the rangeland productivity and crop production for assessing rangeland health. For example, invasion of exotic species, decreased vegetation yield as measured by the availability of palatable forage, increase in annual species and decreased soil fertility and a shift to agricultural practices are some of the indicators used for the assessment of rangeland degradation.

In contrast, pastoralists from Harawa and Hadhkaley Kebeles give more attention to indicators that are related to rangeland productivity than crop production. Both Kebele uses only 10 indicators (Table 14), which are mainly vegetation and soil parameters to measure rangeland health. Soil fertility and a tendency to shift to crop production are not considered by the pastoral communities of these Kebeles to evaluate rangeland degradation.

Table 14: Traditional rangeland degradation indicators based on indigenous ecological knowledge of pastoralist

Attributes	Indicators	**Shinille** *(n = 8)*	**Marmarsa** (*n = 7),*	**Harawa** *(n = 7)*	**Hadhkaley** *(n =9)*
Vegetation	Reduction of palatable grass	√	√	√	√
	Invasion of exotic plants/weeds	√	√	-	-
	Increase of annual plants	√	-	-	-
	Bush encroachment	√	√	√	√
	Decrease of vegetation yield	√	√	-	-
	Decline of plant biodiversity	√	√	√	√
Soil	Increase dust in air	√	√	√	√
	Increase soil erosion by water	√	√	√	√
	Increase soil erosion by wind	√	√	√	√
	Decrease Soil fertility	√	√	-	-
Other	Food insecurity, food aid and poverty	√	√	√	√
	Reduced livestock number per HH	√	√	√	√
	Shift to crop land	√	√	-	-
	Recurrent drought	√	√	√	√
	Poor livestock output	√	√	√	√

Key: n denotes number of respondents; Indicators shown with a check mark (√) mention that all stakeholder were agree

4.3.7. Pastoral perception towards the vegetation of rangeland

Most of the pastoralists (89.5%) from the four Kebeles believe that the composition of rangeland vegetation has changed dramatically over the last decades (Table 15). The common perception among the pastoral communities is that the rangeland productivity has faced multiple challenges. Seven variables (Table 15) were considered to understand the perception of the pastoralists with regard to rangeland current conditions. Over 94% of the respondents have believed that the current rangeland condition in terms of its productivity, as measured by quantity and quality of forage, poor relative to decades ago. The current findings have clearly shown declining trends in the rangelands with regard to grass cover and vegetation. Most Pastoralists have attributed these changes to overgrazing and drought (Table 15). Population growth was considered as one of the least contributors to the declining trends of rangeland health in the study area.Overgrazing is conceived by the pastoralists as the utilization of rangelands beyond their carrying capacity and optimum grazing frequency. Whereas the ultimate outcomes of rangeland degradation are a shortage of fodder and a subsequent death of their livestock, population migration to urban centers to mitigate rangeland migration was rated as the least outcome.

Table 15: Perception of communities toward rangeland assessment, rangeland condition, trend, grasses, and the cause and consequence of rangeland vegetation loss in Shinile Woreda of Somali region, eastern Ethiopia (N=200). N denotes the number of respondents

VARIABLE	**SHINILLE (N=50)**		**MARMARSA (N=50)**		**HARAWA(N=50)**		**HADHKALEY(N=50)**		**TOTAL(N=200)**	
	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
DID THE PASTORALIST EVALUATE RANGELAND CONDITION										
Yes	46	92.0	43	86.0	43	86.0	47	94.0	179	89.5
No	4	8.0	7	14.0	7	14.0	3	6.0	21	10.5
CONDITION OFRANGELAND										
In good condition	1	2.0	2	4.0	2	4.0	6	12.0	11	5.5
In poor condition	49	98.0	48	96.0	48	96.0	44	88.0	189	94.5
TRENDS OF RANGELAND										
Downward trend	48	96.0	48	96.0	48	96.0	49	98.0	193	96.5
Upward trend	2	4.0	1	2.0	1	2.0	1	2.0	5	2.5
The same as before	-	-	1	2.0	1	2.0	-	-	2	1.0
RANGELAND GRASS COVER										
Increasing	1	2.0	1	2.0					2	1.0
Decreasing	47	94.0	47	94.0	47	94.0	48	96.0	189	94.5
The same as before	2	4.0	2	4.0	3	6.0	2	4.0	9	4.5
DECREASE OF RANGELAND VEGETATION										
Yes	46	92.0	45	90.0	47	94.0	46	92.0	184	92.0
No	4	8.0	5	10.0	3	6.0	4	8.0	16	8.0
OPINION FOR MAIN CAUSE										
Overgrazing	33	66.0	20	40.0	26	52.0	26	52.0	105	52.5
Drought	10	20.0	16	32.0	13	26.0	14	28.0	53	26.5
Uncontrolled livestock movement	4	8.0	8	16.0	5	10.0	6	12.0	23	11.5
Increase Population Number	3	6.0	5	10.0	5	10.0	3	6.0	16	8.0
I don’t know			1	2.0	1	2.0	1	2.0	3	1.5
THE CONSEQUENCE OF VEGETATION LOSS										
Shortage of fodder	37	74.0	23	46.0	41	82.0	42	84.0	143	71.5
Death of herds	10	20.0	23	46.0	7	14.0	7	14.0	47	23.5
Increase migration	-	-	1	2.0	-	-	-	-	1	.5
Food insecurity	3	6.0	3	6.0	2	4.0	1	2.0	9	4.5

4.3.8. Pastoralist perception of Soil degradation

Most of the respondents (90%) believe that soil degradation one of the challenges facing rangeland health. Soil degradation in the study area was attributed to four factors, i.e., overgrazing, drought, uncontrolled livestock movement and lack of soil protection (Table 16). A significant portion (over 42%) of the respondents believed that the shortage of quality fodder to soil degradation. The findings of this study show that the ultimate outcomes of soil degradation are similar to that of rangeland. An exception is that there are more respondents (12.6%) that have attributed higher population migration to soil than rangeland degradation. Furthermore, aridity was considered as a new outcome of soil degradation but not for rangeland. According to all respondents, soil degradation is happening in the study and the pastoralists are practicing different soil conservation measures (Table 16). Tree planting was the widely practiced soil conservation measure to increase rangeland productivity and vegetation cover.

Table 16: Perception, causes, consequence and management practice of soil in the study area (N=200). N denotes the number of respondents

	SHINILLE (N=50)		MARMARSA (N=50)		HARAWA(N=50)		HADHKALEY(N=50)		TOTAL(N=200)	
	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
AN INCREASE SOIL DEGRADATION										
Yes	48	96	42	84	46	92	44	88	180	90
No	2	4	8	16	4	8	6	12	20	10
CAUSE OF SOIL DEGRADATION										
Drought	17	34	14	28	16	32	22	44	69	34.5
Overgrazing	21	42	23	46	24	48	15	30	83	41.5
Uncontrolled livestock movement	7	14	6	12	6	12	8	16	27	13.5
lack of Protection	4	8	5	10	2	4	3	6	14	7
I do not know	1	2	2	4	2	4	2	4	7	3.5
CONSEQUENCE OF SOIL DEGRADATION										
Shortage of fodder	25	50	15	30	24	48	21	42.9	85	42.7
Shortage of land productivities	10	20	11	22	13	26	9	18.4	43	21.6
Increase herd death	7	14	12	24	5	10	10	20.4	34	17.1
Increase migration	5	10	8	16	6	12	6	12.2	25	12.6
Change to more aridity	3	6	4	8	2	4	3	6.1	12	6
PRACTICE OF SOIL CONSERVATION ACTIVITIES										
Yes	44	88	45	90	45	90	41	82	175	87.5
No	6	12	5	10	5	10	9	18	25	12.5
MAJOR ACTIVITIES PRACTICED										
Terracing	-	-	-	-	1	2.1	-	-	1	0.6
Tree plantation	25	55.5	27	62.8	27	57.4	30	69.8	99	61.2
Check dam	8	17.8	7	16.3	10	21.3	5	11.6	30	16.9
Waterway	9	20	7	16.3	8	17	6	14	30	16.9
Cutoff drain	3	6.7	2	4.7	1	2.1	2	4.7	8	4.5
CHANGE FROM ACTIVITIES										
Increase Soil productivity	5	10.6	6	14	1	2.1	8	17.8	20	11
Increase land cover	6	12.8	3	7	3	6.4	16	35.6	28	15.4
Both	36	76.6	34	79.1	43	91.5	21	46.7	134	73.6

4.3.9. Traditional rangeland management practices

Area enclosure of the most (98%) widely practiced rangeland management in the study area. The ages of the enclosures range from less than 5 years to up to 20 years but a large proportion (64.7%) fall between 10 – 15 years (Table 17). Whereas only 0.5% of the enclosure are less than 5 years old, the proportion of 20 years old enclosures are also very small (4%). In terms of the distribution of these age classes of enclosures, Shinile Woreda has the youngest enclosure age (Table 17). Although the remaining age classes of the enclosures are different at different study sites, they have been put into a practice across the whole study area starting from the last 10 years ago to the present. Most (80%) of these enclosures are designated as communal but pastoralists also use the combination of communal and private enclosures to provide sustainable fodder for their livestock. Communal enclosures were usually accessible to all members of the communities when feed resources were depleted in open grazing areas during the long dry season. The private enclosures were owned by individual families and controlled to ensure conservation of forage for theirlivestock. In some cases, e.g. Shinile and Marmarsa Kebeles, private enclosures are used for crop production.

There are different management practices to ensure productive rangelands. These are fencing every year, cutting bushes and clearing weeds. The enclosures provide fodder for different categories of livestock but the respondents attributed 33% of their usages by new born and young livestock and 9.5% for lactating cows. A very small (less than 2%) proportion was attributed to foraging by other livestock in addition to new born, pregnant cows, weak or sick cattle and lactating cows during the dry season. Enclosures are usually used during the dry season but 12.5% of the respondents from the study area use then both during wet and dry seasons. With regard to the values of enclosures to provide a sustainable fodder resources throughout the seasons, over 74% of the respondents believe that they are used to mitigate drought and are means to rehabilitate degraded rangelands. When evaluated as a separate entity, both drought mitigation and rangeland rehabilitation have received much less percentage among the respondents (Table 17).

With regard to the continuous use of enclosures as a strategy for a sustainable fodder supply for the livestock, 88% - 96% respondents have decided to continue designating and managing enclosures as a sustainable of fodder resources for their livestock. The values for those who are not opting to continue to use enclosures range from 4% (Shinile Kebele) – 12% (Harawa Kebele). Generally, most respondents (82% - 92%) believed that enclosures have improved productivity (Table 17) but response levels are different across the study area.

Table 17:Status of range enclosure in the study area (n=200)

VARIABLE	**SHINILLE (N=50)**		**MARMARSA (N=50)**		**HARAWA(N=50)**		**HADHKALEY(N=50)**		**TOTAL(N=200)**	
	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
DOYOU HAVEENCLOSURE										
Yes	50	100.0	49	98.0	50	100.0	47	94.0	196	98.0
No	-	-	1	2.0	-	-	3	6.0	4	2.0
KIND OF ENCLOSURE										
Private	2	4.0	2	4.0	-	-	2	4.0	6	3.0
Communal	40	80.0	40	80.0	43	86.0	37	74.0	160	80.0
Both	8	16.0	8	16.0	7	14.0	11	22.0	34	17.0
DURATION OF ENCLOSURE USE										
Less than 5 year	1	2.0	-	-	-	-	-	-	1	.5
5 to 10 years	4	8.0	4	8.0	5	10.0	3	6.0	16	8.0
10 to 15 years	30	60.0	36	72.0	32	64.0	37	74.0	135	67.5
15 to 20 years	12	24.0	9	18.0	11	22.0	8	16.0	40	20.0
More than 20 years	3	6.0	1	2.0	2	4.0	2	4.0	8	4.0
MANAGEMENT TO EMPROVE ENCLOSURE										
Yes	50	100.0	49	98.0	50	100.0	48	96.0	197	98.5
No			1	2.0			2	4.0	3	1.5
TYPE OF MANAGEMENT USED										
Fencing every year	3	6.0	5	10.0	3	6.0	5	10.0	16	8.0
Cleaning Bush and weed	12	24.0	8	16.0	6	12.0	7	14.0	33	16.5
Both	35	70.0	37	74.0	41	82.0	38	76.0	151	75.5
KIND OFANIMAL FEED IN ENCLOSURE PRIMARLY										
Lactating Animal	6	12.0	4	8.0	6	12.0	3	6.0	19	9.5
Pregnant animal	13	26.0	18	36.0	17	34.0	17	34.0	65	32.5
Sick animal	12	24.0	13	26.0	11	22.0	11	22.0	47	23.5
Young animal	18	36.0	14	28.0	16	32.0	18	36.0	66	33.0
All herds	1	2.0	1	2.0	-	-	1	2.0	3	1.5
SEASON ENCLOSURE USED COMMONLY										
Wet season	-	-	-	-	1	2.0	-	-	1	.5
Dry season	42	84.0	46	92.0	45	90.0	41	82.0	174	87.0
Both	8	16.0	4	8.0	4	8.0	9	18.0	25	12.5

ROLE OF ENCLOSURE										
Drought mitigation	5	10.0	5	10.0	5	10.0	7	14.0	22	11.0
Rehabilitation	8	16.0	7	14.0	7	14.0	7	14.0	29	14.5
Both	37	74.0	38	76.0	38	76.0	36	72.0	149	74.5
CONTINUE TO USES AREA ENCLOSURES AS SUSTAINABLE FODDER RESOURCES										
Yes	48	96.0	47	94.0	44	88.0	46	92.0	185	92.5
No	2	4.0	3	6.0	6	12.0	4	8.0	15	7.5
PRODUCTIVITY OF ENCLOSURES										
More productive	43	86.0	41	82.0	46	92.0	42	84.0	172	86.0
Productive	7	14.0	9	18.0	4	8.0	8	16.0	28	14.0
Less productive	-	-	-	-	-	-	-	-	-	-

5. DISCUSSION

5.1. Patch enclosure and localized effects of selected *Acacia* species on herbaceous plant richness and soil properties

5.1.1. Effect of enclosure and *acacia* shade on herbaceous plant species richness

Our study has investigated the effects of enclosures and selected *Acacia* shade on plant richness of study area. Enclosure showed an increase in plant species richness by protecting them from over grazing.Grazing exclusion has been reported to be an effective practice to restore degraded grassland, as vegetation characteristics have been shown to improve under long-term grazing exclusion (Wang, *et al.,* 2015; Zhao, *et al.,* 2011). In the same way, earlier studies in Afar region also reported that enclosed areas have been effective in restoring plant species composition, and cover of herbaceous species richness than the communal, open grazing areas (Ibrahim, 2016). The shade of *Acacia* species has high contribution in increasing plant species richness in arid and semi-arid (Mahgoub, *et al.*, 2016).

Typically in our result, we recorded that the *Acacia* shade provides biological shelters (local refugia) for most of grasses and forbs by protecting them from biotic factors interaction such as grazing by goat, donkey, camel and cattle. Grazing pressure has a significant effect on total vegetation cover, species richness, species composition, diversity and productivity (Gamoun, 2014; Wiebke, *et al.,*2014; Hanke, *et. al.,*2014), and therefore the detailed effect of different grazing pressures on semi-arid rangelands requires careful assessment. Furthermore, these local level refugia ameliorate environmental factor such assoil-water evaporation and wind erosion at enclosures and nearby open grazing areas. *Chloris gayana*was one species recorded under *Acacia* shade at both inside and nearby open grazing area.This could be perhaps attributed to its ability to establish rapidly in degraded areas. This species was reported as persistent and drought resistance (Gohl, 1981). *Chroris gayana* also propagates by stolon in addition to from seeds. The highest grass species richness was recorded at inside enclosures compared to open grazing areas. Nevertheless forbs show highest richness at under *Acacia* shade at both enclosure and open grazing areas. This shows *Acacia* shade is provided high protection for forbs, i.e., it serves as local refugia facilitating the germination of seeds and survivorship.

On the other hand, because of a substantial overgrazing at open grazing area, some grass species were found to be susceptible grazing intensity and confined to enclosures under *Acacia* shade and without it, e.g.*Tragus berteronianus*. The species richness higher in enclosures than open grazing areas could be explained by considering grazing intensity. There is a higher grazing intensity in open grazing areas than enclosures. Therefore, exposure of herbaceous vegetation to the high overgrazing, lack of protection and livestock movements (physical destruction) could be detrimental for variable composition of species between these treatments.Degraded nature of rangelands outside unprotected areas were found to be more degraded than when protected elsewhere (e.g. Bahareh, *et al.*, 2016). Furthermore, Angassa, (1999) assessed the traditional grazing management in southern range land of Ethiopia and reported that heavy grazing pressure might have caused a deterioration in plant species composition and diversity over time. Disturbance prejudiced plant species richness and diversity (Cumming, 1982). This could indicate that grasses and forbs growing inside of enclosure are well protectedcompared to areas outside enclosures. Earlier studies (e.g., Gamoun, 2014), have shown a general decrease in vegetation cover with increasing grazing pressure.

5.1.2. Effect of enclosures and *Acacia* shade on soil chemical properties

The patterns of plant species richness are directly related to resource availability which impact plant growth. This suggests that there are a variety of patterns of species richness along with soil nutrient gradients. Also Vegetation plays an essential role in the process of soil formation through breaking rock particles and enriching soil with organic substance from aerial and subterranean layers (Donahue, 1977).

In our study, pH was not affected by *Acacia* shade. It was nearly the same at both under *Acacia* shade and in areas without it. In contrast to our result, Hagos and Smit (2005) reported significantly low value of soil pH under the shade cover of *Acacia mellifera*. On the other hand, soil pH tends to be slightlymore alkaline in under *Acacia* shade compared to without it. More species richness was also observed under *Acacia* shade. Soil pH was reported as a major factor driving species richness as a fine scale (Palpurina *et al.*, 2017). *Acacia* shade ameliorates moisture, which has a direct impact on soil pH, compared to areas without it. Although the effect of soil pH is confounded with other soil chemical properties, there is a tendency of positive relationships between species richness and increased soil pH. Furthermore, that means *Acacia* shade could be presentmore favorable soil conditions through decomposition of organic matter from plant detritus which increases soil pH. Numerous studies indicated that the increased soil pH could possibly be due to an increase in organic matter accumulation from applied straw or white clover growth. Increases in pH after the addition of organic matter are purported to occur due to the decarboxylation of organic anions (Tang and Yu, 1999). Other studies suggested that basic cations which are released during decomposition increase the pH (Noble and Randall, 1999).

EC rises with the quantity of soluble salts and high value of EC negatively affects vegetation (Pilania and Panchal, 2014 and 2016). Soil salinity increases with soil degradation (Panchal and Pandey, 2002). In this study, soil under *Acacia* shade had shown higher soil EC than without it inside enclosures and open grazing areas. The lower species richness under *Acacia* shade in open grazing area could be due to the negative effect of high salinity perhaps coupled with soil degradation. Although high value of EC was recorded for soil under *Acacia* shade in enclosures, the relatively higher species richness could be attributed to reduced intensity of soil degradation. The observed high electrical conductivity values under tree shade might be due to accumulation of Na^{+}, Ca^{++} and Mg^{++}. High EC value may not imply high species number (Fig. 5). Furthermore, although the positive effects of shade on species number is obvious, there are perhaps other factors which are detrimental for increasing species number. Open grazing areas are usually prone to disturbance which may result in trampling of seedlings limiting recruitment and establishment compared to enclosures. The lower number of species from *Acacia* shade from open grazing area could be due to disturbance although *Acacia* shade in enclosures and open grazing areas provides the same microclimate for plant species.

Abdallah *et al.* (2008) investigated the influence of *Acacia tortilis* trees on the soil nutrient status and that the top soil has higher in OC, pH, EC, available P and exchangeable K underneath as compared to outside the canopy.Similarly our study showed that OC, OM EC availableP and exchangeable K were significantly higher under*Acacia* shade at both inside and outside enclosure. Increased OC and OM content may be due to the accumulation of litters under the canopies at both sites. Other study also shows that OC was increased under *Acacia* (Mahgoub, *et al.*, 2016). This also completely in agreement with our result in which Soil OC and OM were significantly high under *Acacia* shade and declined nearby place where the shadow might not rich. Similarly other studies have reported higher SOC contents in topsoil of arid and semi-arid regions under trees than in open areas (Herrera *et al.,* 2007).Organic materials of plants being returned to the soil led to faster SOC turnover via the accumulation of litter (Steffens *et al.,* 2009) and SOC improvement was caused by microorganisms' decomposition of organic matter (Tanentzap and Coomes, 2012; Steffens *et al.,* 2009). Furthermore, there is a linear relationship between soil factors such as OC and OM and plant diversity and species richness (Abbasi-kesbi *et al.,* 2017).In this study, the soil OC and OM haveshown to be positively correlated with species richness at all treatment. The soil OC can increase plant growth by providing plants with appropriate nutrients (Qiu *et al.* 2013).In semi-arid grassland ecosystems, the maintenance of heterogeneous vegetation and associated topsoil structures areessential for the accumulation of soil OC and OM (Wiesmeier, *et al.,* 2009). The enclosure improves soil organic matter of the rangeland by reducing wind erosion due to increased vegetation cover at inside. Increases in soil OC and OM resulted in decreased soil erosion by wind and water in this region due to increased vegetation cover, which enable nutrients to easily fix to the soil surface after livestock exclusion (Chen, *et al.,* 2012). Besides, grazing protection enhanced the soil aggregation as the physical protection of soil OC and OM (Wiesmeier *et al.*, 2012). The observed high values of soil factors such as OC, OM, P, Na, Ca and K could be attributed to the local refugia effect of *Acacia* shade and enclosures and such improved soil chemical properties was also previously reported (Nuray-Müftüoğlu and Gokkuş, 2016).

Adequate grazing management may balance provisioning and regulating ecosystem services (Onatibia, *et al.,* 2015). The tradeoff between ecosystem conservation and utilization should thus be taken into consideration by local rangelandmanagers. After a certain number of years of fencing, appropriate management, such as rotational grazing and mowing, should be carried out. On the one hand, moderate grazing can increase the community stability and biodiversity and pastoralists have benefited directly from adding animals. Extensive enclosures and grazing management could improve the grassland utilization efficiency and foster sustainable development of the social-ecological system.

In the study area, soil degradation is linked to overgrazing and this threatens the conservation of soil organic matter and other soil nutrients (Sebastia, *et al.,* 2008). This result shows a strong influence of overgrazing on the soil chemical properties affecting species richness. Rangeland management coupled with amelioration of microclimate by *Acacia* shade resulted in a high species richness compared to exposed areas which are prone to soil degradation. Species richness and soil chemical nutrients such as EC, OC, OM and P exhibit significant correlation. This result indicates a significant relationship between species richness and soil chemical properties. Interactions between species richness and soil chemical properties may be attributed to changes in vegetation during the restoration process through enclosure.

5.2. The effect of enclosure and *Acacia* shade on phenotypic plasticity of some maternal traits of selected grasses

The study showed that plant height increased at under *Acacia* shade for all selected species at both inside and outside of enclosures. This is due to those plants tending to grow high under shade with "thickets" of species under a shade. However, the height of all plant relatively decreased as the plant is exposed to sun light directly at both inside and outside of enclosure. It is widely accepted that plants may facilitate the growth of other plants when they increase the availability of a limiting resource, but negatively affect their growth when they compete for it (Callaway 1995; Holmgren, *et al.,* 1997). Dohn *et al*. (2013) concluded that woody plants facilitate under-story productivity under conditions of water stress, but out-compete them under wet conditions. Since our study is located in a semi-arid rangeland, *Acacia* the shade has positively affected the height of all selected grass species. Such an effect, which consistent with the stress-gradient hypothesis (Callaway, *et al.*, 2002), could due to that woody plants improve water conditions for under-story plants, e.g. through hydraulic lift or by reducing under-story evapotranspiration (Ludwig, *et al.,* 2004). Our resultsshowed the height of all selected species haveincreased under *Acacia* shade and its effect on height was found to be positive. The height of *Aristida kelleri, Cenchrus ciliaris, Eriochloa fatmensis, Dactyloctenium aegyptium* and *Tragus berteronianus* was significantly higher at under *Acacia* shade. However, the height of *Eragrostis cilianensis*significantly increased at only inside enclosure under *Acacia* shade.

Except for *Aristida kelleri,* all selected plant species showed increasedtiller number at inside of enclosure and also under *Acacia* shade in open grazing areas. However, it was significantly reduced for all species at only outside of enclosure where the shade could not rich. This is due to lack of protection which leads to heavy grazing. This indicates the enclosure as well as the *Acacia* shade at inside of enclosure protects all plant from the exposure to livestock but in different ways. Whereas enclosures induce increased plant height through controlled grazing with limited livestock, *Acacia* shade ensures inaccessibility of grasses for grazers. The tiller number of *Cenchrus ciliaris, Dactyloctenium aegyptium* and *Tragus berteronianus* has increased significantly at only inside enclosure. On the other hand, the tiller number for *Eriochloa fatmensis* hassignificantly lowered in open grazing areas without *Acacia* shade. On the other hand, tiller numbers of *Eragrostis cilianensis* were found to below and remain similar under *Acacia* shade and with no shade both inside enclosures and open grazing areas. Tiller number influences seed yields of grasses and adaptability to grazing pressure, determine photosynthetic rates and are used as a source of food reserves (Laidlaw, 2005). The number of tillers in a plant determines the biomass production and the quality of forage yield (Mganga, *et al.*, 2013; Skinner and Moore, 2007). The tillers contain leaves which have more easily digestible nutrients and less structural components especially from the newly developed tillers with young leaves (Wilson, *et al.*, 1991).

Ourresults suggest the studied grasses have differentseed numberin all treatments. This may be attributed to the morphological characteristics of the species as determined by their genetic featuresand adaptability to different soil water conditions in semi-arid location (Masuka, *et al.*, 2012; Mganga, *et al.*, 2013). Furthermore, the counted numbers of seeds from the four locations were different among and within six species selected for this study. The dominant species of the area *Eragrostis cilianensis*, hasproduceda largenumber of seed compared toall other species. Generally, seed number hasincreased at inside of enclosure for all speciesin all treatment and fewer seed number was recorded for all species from open grazing areas. Such variations could be due to the intensity grazing which reduces tiller number of the grasses. Whereas enclosures are exposed to a controlled grazing by a limited number of livestock for a given period of time, open grazing areas are continually grazing throughout the year. Heavy grazing reduces seed production of grass species by affecting the allocation of resources for reproduction through reducing active surface areas for photosynthetic processes, as well as through direct removal of flowers and seeds (O'Connor and Pickett, 1992; Hoshino, *et al.*, 2009). Furthermore, perennial grass species that reproduce only from seeds are palatable to herbivores, with low seed output potentials and short seed longevity might disappear in the system due to sustained heavy grazing (O'Connor, 1991 and 1996). As grass species have evolved as perennials for vegetative forage yield, they have very low seed productivity (Chatterjee and Das, 1989).Variation in seed numbermay be the result of a myriad of factors (Wulff, 1986). For example, Winn (1991) suggested that plants may not have the capability of producing a completely uniform seed weight, simply as a result of variations in resource availability (e.g., soil moisture) during seed development. The range of size variation among seeds is expected to increase if individual seeds compete for resources during development (Rees, 1996). It is very unlikely that a plant, even if one seed weight was always superior, could produce exact copies of this particular seed weight. The observed higher seed weight under *Acacia* shade and enclosures compared to open grazing areas could be attributed to difference in soil factors. Soil chemical properties have shown higher values in *Acacia* shade and enclosures than open grazing areas.

5.3. Impacts of enclosures on plant diversity and richness: local and regional species pool perspectives

5.3.1. Floristic composition and richness at local-regional level

The study has shown difference in species diversity and richness along the gradient of habitat heterogeneity. Habitat heterogeneity is hypothesized to be the dominant force structuring assemblages of biodiversity of rangeland. Our original hypothesis was that changes in species diversity and richness along the gradient of landscape are driven by establishment of enclosures. In the study area, increasing value of enclosure over time (as feed shortage encouraged people to conserve grasses and other important woody vegetation through enclosure), has influenced both herbaceous and woody species distribution across the landscape. The total species richness ofherbaceous species have increased drastically at local level, i.e., enclosures perhaps due to less grazing intensity and management. But herbs species richness has declined as the function of distance from enclosures, i.e., 1 km and 2 km distance from enclosures, due to soil degradations and lack of management. Furthermore, these differences in species richness between local and eco-regional species pool could be linked to differences in habitat factors. A similar pattern has also been found in grassland by Marteinsdóttiret, *et al*. (2014). Declines in species diversity and species richness can have detrimental consequences for ecosystem productivity, stability, and resilience (Johnson, *et al.*, 1996; Tilman *et al.*, 1996), including further biodiversity loss. Earlier studies have shown that herbaceous species richness increased after grazing removal in semi-arid grasslands in Arizona (Brady *et al.*, 1989). Floyd *et al.* (2003) also found greater species richness in all 6 enclosed sites relative to grazed sites in semi-arid grasslands in New Mexico.

Woody species richness has shown an opposite trend compared to herbs, i.e., it has significantly declined inside enclosures but has increased with distance (1 km and 2 km) from enclosures. Such observed variations could be attributed to (1) overgrazing that reduces herb richness and establishment and (2) the selective removal of woody plant species inside enclosures. In our study areas, different rangeland management regimes have played key roles in determining species turnover at local and eco-regional scales. Grazing exclusion was found to be a useful an ecological management toolthat excludes grazing and associated damagesto allowthe grassland to enter a state of self-recovery (Lunt, *et al.,* 2007).

5.3.2. Herbaceous and woody species diversity

The result of study shows that the local species pool had relatively higher herbaceous species diversity than eco-regional species pool. This could be due to protection of local species pool from overgrazing and physical destruction bylivestock. Earlier studies, e.g.Abdulatife andEbro (2015) have shown that higher frequency of highly palatable grass species inside enclosure. The mean values for grass and forb species diversity at local species pool were significantly higher than eco-regional species pool circulated around the enclosure. However, woody species diversity at local species pool were significantly reduced compared with eco-regional species pool due to interference of pastoral community of the area partake in cutting trees for firewood, construction purpose (for fencing and house) and animal feed from areas near to the settlement. The impact of human factors in determining species diversity was also reported previously (GemedoDalle *et al.*, 2006) and a decline in species diversity due to disturbance (Diress, 1999; Belaynesh, 2006) and deforestation (Baars and Said, 2002).

5.4. Assessment of perception and indigenous knowledge of pastoralists

5.4.1. Rangeland degradation indicators

Traditional ecosystem indicators are key soil or plant community characteristics that are sensitive to change in the environment (Pellant, *et al.,* 2005). They reflect complex ecosystem processes that are too difficult or expensive to be measured directly. Traditional ecosystem indicators provide information about the current status of rangeland ecosystems. The indigenous ecological knowledge of pastoralist on rangeland management is the result of their historic eco-friendly management over time and the best choice to identify indicators (Fernandez-Gimenez, 2000;

Bahareh, *et al.,* 2016). As is generally known, local knowledge is a rich source of information about land degradation, environmental sustainability, and their respective indicators. Local ecological knowledge of pastoralists has the capability to be used for the management of natural resources. This capability will substantially increase if it is linked to a more general scientific understanding (Reed, *et al*., 2007).

Looking more closely into the indicators list, it can be understood that pastoralists' ecological knowledge on rangeland degradation was based on the connection between people, environmental conditions, and ecosystem productivity (Angassa, *et al.,* 2012). It is also known that local knowledge-based management strategies could ensure a focus on the optimal use of species and vegetation types that are most valuable to local communities (Sulieman, *et al*., 2012). Herders recognize all the desirable and undesirable plant species by local names (Gemedo-Dalle, *et al*., 2006). The herders categorized forage plants into desirability classes based on livestock preferences. Therefore trends from indicators measured regularly provide clues about the response of the system to management and they preferred these indicators for the degradation assessment of their own rangelands during the discussions and interviews (Oba, 2012). Reducing soil production mainly reduces vegetation and increases desertification. Therefore, pastoralists of the study sitesconsider soil degradation as indicators for assessing and evaluating the degradation of their own rangelands.

Generally, the study shows that Shinile Woreda pastoralist's are realizing the biophysical changes in the rangeland ecosystems caused by overgrazing and other natural and anthropogenic event. In the study area, pastoralists focus more on the indicators that related to rangeland productivity than crop production. For example, all pastoralists from four sites (Shinile, Marmarsa, Harawa and Hadhkaley Kebele) have 16 traditional ecosystem indicators to assess the health of rangelands but the importance is different among the sites. Communities from Shinile and Marmarsa have valued all of the 16 indicators due to their different livelihood strategies, i.e., they stated practicing agro-pastoralism. These shows, pastoral communities of Shinile and Marmarsa are turning to crop cultivation in addition to livestock production. Although the participation of pastoral households in crop cultivation is generally accepted as livelihood diversification in response to economic stress and the rapid expansions of cultivated land have been taking the area of rangeland. Therefore, natural resources stress could be considered as a response factor for the observed differences in the types of traditional ecosystem indicators in Shinile and Marmarsa Kebeles for assessing rangeland status.

However, the pastoralist of these Harawa and Hadhkaley Kebele concern on indicators that related to only rangeland productivity. Therefore, the pastoral communities of this Kebele focus on livestock production for sustain their life and indicators associated with agro-pastoralism were found to be unknown. The absence of some traditional ecosystem indicators, e.g. shift to cropland, decrease soil fertility, vegetation yield, increase in annual plant and invasive plant species, for assessing rangelands productivity because they are entirely pastoralists. An indicator such as invasive species (*Parthenium hysterophorus* and *Prosopis juliflora*) was not a key factor for the communities from these sites because these species did not yet extend their range to Hadhkaley and Harawa Kebeles.

5.4.2. Pastoral perception towards rangeland condition

Most of the pastoralists of the Somali region believed that the rangeland vegetation composition dramatically altered within the past decades (Kassahun, *et al*. 2008). Similarly local communities of our study area perceived that the pastoral production system was facing numerous challenges and they ranked rangelands condition in a downward trend. Rangeland degradation is caused by multiple factors including overgrazing and drought (Gamoun, *et al.*, 2011), uncontrolled livestock movement (Dabasso, *et al.* 2012). Another studyhas also revealed the main factors affecting rangeland productivity are recurrent drought, rangeland degradation, overgrazing, erratic rainfall and expansion of crop cultivation (Dika, *et al*, 2016). Overgrazing has also a major impact on desert rangelands, primarily through its effect on loss of species diversity and lack of opportunity for plant regeneration. Some of the major impact of overgrazing are a significant reduction intotal vegetation cover, species richness, species composition, diversity and productivity of rangeland (Gamoun, 2014; Hanke, 2014).These factors have considerable impacts on the productivity of rangelands and livelihoods of pastoralist in our study area too.

The consequences of rangeland degradation are noticeable in many ways. One of the most identified impacts of rangeland degradation in the study area is shortage of fodder due to a decline in grass cover and increase in unpalatable species, e.g. bush encroachment. Most of the pastoralist haveattributed rangeland degradationto the loss of palatable grass species and decline in forage base, which in turn result in a death of livestock and a decline in livestock productivity (milk and meat).

According to the opinion of the most pastoralists of study area, the grass composition of rangeland has intensely reducedwithin the past decades particularly for the most important perennial grasses. These were replaced by less palatable annual grasses, exotic weeds such as *Parthenium hysterophorus* and unpalatable woody vegetation such as *Prosopis juliflora*. The study has revealed that groups of herders and elders pastoralists were repeatedly raised the issues of recurrent drought as a factor affecting the productivity of rangelands. Therefore, recurrent drought, which reduces the productivity of their rangeland, was one of driving factors for the observed high number of enclosures in the study area. Uncontrolled livestock movement and population increase areadditionalfactors which lead to rangeland degradation. Furthermore, the perceived degradation of rangeland by the communities of the study area could be attributed to overgrazing and lack of management of grazing areas. In arid Ethiopian landscapes, population growth, intensification livestock population, increasing demand for natural resources, and environmental degradation create environmental stresses that have considerable socio-economic and ecological consequences (Bolling and Schulte, 1999; Mouat, *et al.,* 1997; Sinclair and Fryxell, 1985; UNCCD, 2000; UNCED, 1992).Rangeland degradation is globally becoming a major ecological problem due to human activities, climate change, and poor management (Mcsherry, *et al.,* 2013).Recent increases in human and livestock populations and decreases in the availability of grazing lands are also putting the rangeland resource under increased pressure (Coppock 1994; Helland 1997). Among these, overgrazing is regarded as a dominant factor in causing grassland degradation (Akiyama and Kawamura, 2007; Courtois, *et al.,* 2004). Previous studies have shown that degraded grassland induced by overgrazing is characterized by reductions in vegetation coverage, biodiversity, and biomass (Schoenbach, *et al*., 2011).

5.4.3. Pastoralist perception on Soil degradation

Soil is the most important component of rangeland ecosystems. Moreover it offer services to the human societies and make the Earth system stable (Keesstra, *et al.,* 2012; Berendse, *et al.,* 2015). The driving forces behind rangeland soil degradation in the study area were identified as overgrazing, recurrent drought, uncontrolled livestock movement and lack of protection. Soil of rangelands has undergone rapid transformations as a result of factors such as overgrazing, deforestation, woody-plant encroachment, and invasion by non-native plant species (Wilcox and Thurow, 2006). Each of these factors has led to a reduction in the forages available for grazingleading to rangeland degradation in terms of its quality. Overgrazing is considered to be most important factor affecting vegetation and the major cause of soil degradation in all rangelands of the world (Sharafatmandrad, *et al.,* 2014; Angassa, 2014). In the study area, overgrazing by livestock has reducedgrass cover from many grazing area exposing the latter to wind erosion. Therefore, the perceived soil degradation by the pastoral communities of the study area could be attributed wind erosion that washes away important soil nutrients. Furthermore, degraded rangelands are also susceptible to water erosion. This is because of reduced infiltration capacity of soil which leads to surface run-off (Dika, *et al.,* 2016). The observed shortage of fodder in the areas is due to soil physic-chemical processes manifesting in the study area.

The communities of the study area indicated that enclosure increases fodder security for their livestock during environmental stress such as extended drought. This rangeland management approach is widely practicedin many country in order to restore vegetation and soil properties in rangeland ecosystems. Therefore, enclosure improves availability of soil nutrients for plant growth in enclosures compared to where this is not practices in the study. Numerous studies have demonstrated that both vegetation characteristics and soil properties have improved after grazing exclusion in recent years (Courtois, *et al.,* 2004; Deleglise, *et al.,* 2011; Hoshino, *et al.,* 2009). For example, several studies demonstrated that vegetation coverage, height, and species richness increased following grazing exclusion in arid areas of the Loess Plateau, China (Cheng, *et al.,* 2011). Other studies found grazing exclusion to improve soil fertility in grassland (Tanentzap and Coomes, 2012). Soil nutrient, plant coverage, and richness significantly increased after grazing exclusion in the Junggar Basin and a in the desert of Hexi Corridor, China (Zhang and Zhao, 2015; Rong, *et al.,* 2014). Examining the effectiveness of grazing exclusion on vegetation and soil and determining the duration required for significant improvement would provide valuable insights into grassland restoration and management.The impact of enclosure management on soil properties and microbial biomass in a restored semi-arid rangeland indicated that the contents of OC in different areas under study were approximately equal (Mureithi, *et al.* 2014).Grazing exclusion is regarded as a dominant factor in causing rangeland degradation through affecting organic compound (Chen and Tang, 2016).

5.4.4. Traditional rangeland management practices

One of the most relevant challenges faced by pastoralists today is to access sufficient pasture resources to sustain their livestock through both good and drought years. To cope with this challenge, the communities in the Ethiopian Somali pastoral system have traditional rangeland management methods which have been administered by leaders/elders of the community. All of them repeatedly raised that, the use of traditional range enclosures locally known as *seero* is widely practiced in their area for dry season grazing.Traditional range enclosures can be used as a method of rangeland restoration where rangelands are often heavily grazed to allow the herbaceous vegetation diversity to recover (Courtois, *et al.,* 2004; Deleglise, *et al.,* 2011; Hoshino, *et al.,* 2009). Therefore, the uses of range enclosure in the Shinile pastoralists were a common practice like other pastoralist of the country and the world. Almost all communities own enclosure and use as the traditional grazing land management. Broadly, there are two types of enclosure (*seero*) in the region: private and communal enclosure; the communal one also further divided into government; NGO supported and cooperative. Also there are two types of private enclosures; "*sera*" within an existing farm, and "*beer*" outside the farm. Communal enclosures were accessible to all members of the communities when feed resources were depleted in communal grazing areas during the long dry season under the order of leaders and/or elders. The private enclosures were owned by individual families and controlled to ensure conservation of forage for the animals. Additionally in Shinile and Marmarsa kebele pastoralist began to use private enclosure for farming activities.

Most of the Shinile area is pastoralist and the territory of the Issa clan. The Issa strongly believe that all resources in Issa areas are communal and it is relatively more difficult to establish private enclosures in Issa areas than in other areas. Accordingly, most of pastoralist of these area own communal enclosure than private enclosure. Despite this, there have been instances of private enclosures emerging in Issa areas which are very few in quantity (Alison, and Solomon, 2011).

Enclosures offer an opportunity to develop a more intensive communal resource management system. Since most of the pastoralists in the study area believed that the rangeland vegetation composition dramatically reduced within the past decades particularly for the most important perennial grasses, establishment of enclosure for effective in restoring rangeland vegetation become major indigenous activity for the study site community. Similarly Ibrahim, (2016) identified that the enclosure areas have been effective in restoring plant species composition, biomass and cover of herbaceous species. Additionally, the establishment and promotion of communal enclosures and drought season reserves in the areas could help reduce grazing pressure on outside communal lands, in this manner creating access to fodder banks and improving soil restoration for rangeland development (Teshome, 2016).

The decision to establishment of communal enclosures in study area followed the Critical drought in 1983 which led to massive livestock mortality (Alison and Solomon, 2011). At the beginning, private enclosures were initiated in the study area by wealthier households who split their family to allow them to feed milking animal's atthe main settlement of Shinile (Gezu, 2011). According to the response of elders, the establishment first private enclosure in the area was estimated as thirty five years ago. However 1984-1988 due to herd's recovery and seasonal movement was reinitiated; the majority of the private enclosures were abandoned in Shinile (Gezu, 2011). Alternatively 1998 high rains were recorded in Shinile area. Some pastoralists replanted their previous enclosures to take advantage of crop production.

From 2000 to 2009 increasing settlement, linked to access to water points and other basic services such as health and education were stablished in most part of the area. These leads increase the number of privately owned and communal enclosures with the intervention of community leader, elder and government development. In addition, increasing drought; Herds were depleted and the majority again stopped seasonal movement; Rangeland enclosure practice was reinitiated in Shinille with high enormousness until now days. At that moment, majorities of communities of our study site start to exercise enclosure within the period of 10 to 15 years ago due to access to water points and other basic services provided by government. Furthermore increasing of recurrent drought which reduce the productivity of their rangeland were another reason to inforce all the community to stablish enclosure. Generally the enclosure areas have been effective in restoring plant species composition, and cover of herbaceous species richness than the communal grazing unfenced area (Ibrahim, 2016). The enclosure areas were in a better condition than the peripheral grazing areas.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The results of the study can be vital for the development and sustainable management of rangelands in arid environments. Protection of rangeland by construction of enclosure is widely considered to be a simple and effective method for restoring the herbaceous vegetation and soil chemical properties in degraded arid and semi-arid rangelands. In our study, herbaceous species richness and diversity, seed production and parental body size of selected grass species and soil chemical properties were improved by the presence of either *Acacia* shade or enclosure.This indicates, patch enclosure and *Acacia* shade have great advantage for herbaceous species conservation and increase soil chemical properties of rangelands of study area. Determining the relationship between soil and plants is a useful way to better understand the ecosystem condition and can help to manage the rangeland ecosystem.

Unlikely, woody species richness were reduced at inside enclosure, but increased significantly at eco-regional species pool. The result of Shannon-Weiner index also showed that local species pool were lower in plant diversity than both ecological and regional species pool. Normally species diversity was reduced at local species pool due to anthropogenic action which specifically affects woody species. Therefore, enclosures enhance only herbaceous species richness due to exclusion of livestock. There is considerable evidence that livestock grazing and anthropogenic action strongly affects the diversity, richness, and composition of rangeland vegetation and alters the soil productivity of rangeland. Protection to exclude livestock grazing and low human interference were widely considered to be an effective in conservation of rangeland.

The study showed that the pastoralist identified rangeland degradation indicators based on their indigenous knowledge which describes rangeland degradation such as: vegetation, soil and other indicators related to climate, way of life and productivity of rangeland. The finding shows, rangeland vegetation composition and soil degradation were dramatically altered within the past decades. Factors that triggered vegetation and soil degradation include: overgrazing, drought, uncontrolled livestock movement, increase population number and lack of protection. Therefore, the communities recognize both vegetation and soil degradation as a decline in the primary productive capacity of rangeland resources. These enforce the community to continue the use of enclosures as traditional rangeland management practices. The current condition of rangelands can be enhanced through establishment of enclosures which is used in rehabilitation, conservation, and management. This would involve the strengthening of the indigenous knowledge of pastoralists in rangeland degradation management activities.

6.2. Recommendation

The plant biodiversity of rangeland in the study area is declining. The reasons are many interrelated factors like, anthropogenic human action, soil rangeland degradation, overgrazing, recurrent drought, erratic rainfall and others. This has also considerable impacts on the livelihoods of pastoralist and rangeland productivity. The unique knowledge of communities, the construction of enclosure in the area will not further functioning well without the interference of researchers. The problems affecting the plant biodiversity of rangeland should clearly be regarded as community and societal problems and not simply the only concern of pastoralist. This mean it should be the concern of all stakeholders: government organization, research institution, private sectors, any local and international NGOs, pastoralists, public and etc.

Therefore, the following recommendations are made for the future interventions by the researcher.

Scientists, natural resource managers and development practitioners need to not only recognize the importance of local and traditional knowledge, but also to consider it in all efforts directed towards managing the natural ecosystems. Efforts should be made to encourage involvement of the local communities in any management plan to ensure sustainable use of the natural resource.

Traditional knowledge of the local inhabitants is an integral part of the desert ecosystem; its maintenance should be considered as a priority integrated with the effort of the conservation of biodiversity and ecosystem services. The future development direction in Shinile Woreda and other part of Ethiopian Somali region should support indigenous knowledge of pastoralist in natural resource management in general and rangeland management in particular. All above mentioned stakeholders should stand beside pastoralist in supporting and integrating indigenous and technical knowledge of pastoralist for sustainable management of rangeland. Management of traditional enclosure, mobility and herd splitting should be inextricably linked and managed in accordance to customary institution of pastoralist. Rangeland development and extension services of the government should be built on pastoral indigenous rangelands knowledge. Local and regional monitoring of rangelands problems should use local knowledge to focus the problem in detail. Any rangeland development policy and programs should take into account indigenous knowledge of pastoralist and policies aimed to improve livelihoods of pastoralist should consider the structure of pastoralists. Impacts rangeland problems induce on pastoralist livelihood should be taken as whole community problems. Government and NGOs should give considerable attentions to pastoralist during the time in which the productivity of rangeland and pastoralist decline.

7. REFERENCE

Abate, T., Ebro, A., & Nigatu, L. (2010). Traditional rangeland resource utilization practices and pastoralists' perceptions on land degradation in south-east Ethiopia, *Trop. Grasslands, 44*, 202–212.

Abdalla, M. S., Babiker, I. A., Al-Abrahim, J. S., Mohammed, A. E., Elobeid, M. M., & Elkhalifa, K. F. (2014b). Fodder potential and chemical composition of *Acacia nilotica* fruits for livestock in the drylands of Sudan. *International Journal of Plant, Animal and Environmental Science*, *4 (*1), 366-369.

Abdalla, M. S., Babiker, I. A., Idris, A. M., & Elkalifa, K. F. (2014a). Potential nutrient composition of *Acacia seyal* fruits as fodder for livestock in the drylands in Sudan. *Department of Analytical Chemistry, 1,* 25-30.

Abdallah, F., Noumi, Z., Touzard, B., Ouled Belgacem. A., Neffati, M., Chaieb, M. (2008). The influence of *Acacia tortilis* (Forssk.) Subsp. Raddiana (Savi) and livestock grazing on grass species composition, yield and soil nutrients in arid environments of South Tunisia. *Flora 20,* 116-125.

Abdulatife, M., & Ebro, A. (2015). Assessment of pastoral perceptions towards range and livestock management practices in Chifra District of Afar Regional State, Ethiopia. *Forest Res 4,* 144. doi:10.4172/2168-9776.1000144

Abebe, A., Tolera, A., Holand, Ø., Ådnøy, T., & Eik, L. O. (2012). Seasonal variation in nutritive value of some browses and grass species in Borana rangeland, southern Ethiopia. *Tropical and Subtropical Agroecosystems*, *15*, 261- 271.

Abule, E., Snyman, H.A., & Smit, G.N. (2007). Rangeland evaluation in the middle awash valley of Ethiopia: I. Herbaceous vegetation cover. *Journal of Arid Environ.25* (271).

Abule, E., Snyman, H.A., & Smith, G.N. (2005): The influence of woody plants and livestock grazing on grass species composition, yield and soil nutrients in the Middle Awash Valley of Ethiopia. *Journal of Arid Environ. 60,* 343-358.

Agele, S. O., Ewulo, B. S., & Oyewusi, I. K. (2005). Effects of some soil management systems on soil physical properties, microbial biomass and nutrient distribution under rain fed maize production in a humid rainforest Alfisol. *Nutrient Cycling in Agroecosystems, 72*, 121-134.

Agricultural Development Project Office of Erer wereda (ADPO) 2004. Assessment report of the meteorology and crop production in Erer wereda. Annual report, Dire Dawa.

Ahmad, I., Ahmad, M. A., Hussain, M., Ashraf, M., & Ashraf, M. Y. (2011). Spatial-temporal variations in soil characteristics and nutrient availability of an open scrub type rangeland in the sub-mountainous Himalayan tract of Pakistan. *Pakistan Journal of Botany*,*43*(1), 565-571.

Akiyama, T., & Kawamura, K. (2007). Grassland degradation in China: Methods of monitoring, management and restoration. *Grassland Sci.,53*, 1–17.

Alemayehu, M. (2004). Pasture and forage resource profiles of Ethiopia. Alemayehu Mengistu and Associates, Addis Ababa, Ethiopia.

Alemayhu, M. (2006). Range Management for Eastern Africa; concepts and practices,RPSUD (Spounves) A.A.U Printed press Addis Ababa, Ethiopia.

Alison, N., & Dr. Solomon, D. (2011). Review of pastoral rangeland enclosures in Ethiopia, PLI Policy Project. *Feinstein international center*, Tufts University, USAID.

Amaha, K. (2002). Potentials, roles and constraints of pastoralism and agro pastoralism in Ethiopia. Merewa: *A quarterly journal, 12,* published by Ministry of Information, Addis Ababa, Ethiopia.

Angassa, A. (1999). Range condition and traditional grazing management in Borana. An MSc Thesis presented to the school of Graduate Studies of Alemaya University of Agriculture, Ethiopia. August 12-14, 2004. *ESAP, Addis Ababa.* 2(284).

Angassa, A. (2014). Effects of grazing intensity and bush encroachment on herbaceous species and rangeland condition in southern Ethiopia. *Land Degrad. Dev., 25*, 438–451.

Angassa, A., & Oba, G. (2007). Relating long-term rainfall variability to cattle population dynamics in communal rangelands and a government ranch in southern Ethiopia. *Agricultural Systems, 94,* 715-725.

Angassa, A., & Oba, G. (2008). Herder perceptions on impacts of range enclosures, crop farming, fire ban and bush encroachment on the rangelands of Borana, Southern Ethiopia. *Human Ecology, 36,*201-215.

Angassa, A., Oba, G., & Stenseth, N. C. (2012). Community-based knowledge of indigenous vegetation in Arid African Landscapes, Consilience. *The Journal of Sustainable Development, 8*, 70–85.

Baars, R.M.T., & Said, M.A. (2002). Pastoralists' perception of rangeland degradation in Eastern Ethiopia. *J. Nomadic People.* 6(1).

Badshah, L., Hussain, F., Perveen, S., & Sher, Z. (2012). Seasonal variation in the macromineral in some woody and herbaceous forage in rangeland District, Tank, Pakistan. *Journal of Medicinal Plants Research*,*6*(25), 4167- 4175.

Bagayoko, M., Alvey, S., Neumann, G., & Buerkert, A. (2004). Root-induced increases in soil pH and nutrient availability to field-grown cereals and legumes on acid sandy soils of Sudano-Sahelian West Africa. *Plant Soil*, *225*(1), 117-127.

Bahareh, B., Hossein, B., Ahmad A. S., Mohammad R. S., & Mohsen S. (2016). Rangeland degradation assessment: a new strategy based on theecological knowledge of indigenous pastoralists.*Solid Earth*, 7, 611–619.

Barrow, E., J. Davies, S. Berhe, V. Matiru, N. Mohamed, W. Olenasha, M. Rugadya. (2007). Pastoralist's species and ecosystem knowledge as the basis for land management. IUCN Eastern Africa Regional Office. Policy Brief No. 3 (of 5). Narirobi, 4p. Accessed at:

Barry, S. J. (2011) Current findings on grazing impacts of California's special status species. *Keeping Landscapes Working: A Newsletter for Managers of Bay Area Rangelands.* University of California Cooperative Extension, Santa Clara 7, 2-6. URL:

Bationo, A., Kihara, J., Vanlauwe, B., Waswa, B., & Kimetu, J. (2007). Soil organic carbon dynamics, functions an management in West African agro-ecosystems. *Agricultural Systems*, *94*, 13-25.

Behnke, R.(1994). Natural resource management in pastoral Africa. *Dev. Policy Rev., 12*, 5–27.

Behnke, R. H. (1984). Open range management and property rights in pastoral Africa: A case study of spontaneous range enclosures in south Darfur, Sudan. *Pastoral Development Network paper, 20f*, London. Overseas Development Institute.

Behnke, R. H. (1988), Range enclosures in central Somalia. *Pastoral Development Network paper 25b*, London. Overseas Development Institute.

Behnke, R. H., & Scoones, I. (1993). Rethinking range ecology: Implications for rangeland management in Africa. In Rangeland Ecology at Disequilibrium: New Models of Natural Resource Variability and Pastoral Adaptation in African Savannas, ODI, IIED/Commonwealth Secretariat, London.

Belaynesh, D. (2006). Floristic composition and diversity of the vegetation, soil seed bank flora and condition of the rangelands of the Jijiga zone, Somali Regional State, Ethiopia. Msc thesis, Haramaya University, Ethiopia.

Belete, S., Hassen, A., Assafa, T., Amen, N., & Ebro A. (2012). Identification and nutritive value of potential fodder trees and shrubs in the Mid Rift Valley of Ethiopia. *The Journal of Animal and Plant Science*, **22** (4): 1126-1132.

Belyea, L. R., & Lancaster, J. (1999). Assembly rules within a contingent ecology. *Oikos, 86*(3), 402–416.

Benjamin, B., David Nogue´ S., Michael, K. B., John, C. D. I., Peter, M. J., Nathan, J. B. K., Jean-P. L., Naia M., Brody S., Jens-Christian S., Cyrille, V. C. R., & Brian, J. E. (2015). Linking environmental filtering and disequilibrium to biogeography with a community climate framework. *Ecological Society of America*, *96*(4), 972–985.

Berendse, F., van Ruijven, J., Jongejans, E., & Keesstra, S. D. (2015). Loss of plant species diversity reduces soil erosion resistance of embankments that are crucial for the safety of human societies in low-lying areas. *Ecosystems, 18,* 881–888.

Berhanu, A., & Feyera, A. (2009). Economic values of pastoralism in Ethiopia. In: Beyne T., Bezabih E. and Degnet N. (ed). *Proceedings of the 11th Annual Conference of the Agricultural Economics Society of Ethiopia.* Agricultural Economics Society of Ethiopia. May 2009, Addis Ababa.

Berhanu, W., & D. Colman, (2007). Farming in the Borana rangelands of southern Ethiopia: The prospects for viable transition to agro-pastoralism. *Eastern African Social Science Review XXIII* (3), 79–101.

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications 10,* 1251-1262.

Berkes, F., Kislalioglu, M. Folke, C., & Gadgil, M. (1998). Exploring the basic ecological unit: Ecosystem-like concepts in traditional societies. *Ecosystem, 1,* 409-415.

Beruk, Y., & Tafesse, M. (2000). Pastoralism and agro-pastoralism: Proceeding of the 8th Annual Conference of Ethiopia Society of Animal production Addis Ababa, Ethiopia, 24-26 August 2000. Past and present. pp. 54-65.

Blench, R. 2000. Extensive Pastoral Livestock Systems: Issues and options for the future. FAO Japan Cooperative Project GCP/JPN/005/JPN, Collection of Information on Animal Production and Health.

Blench, R., & Sommer, F. (1999). Understanding rangeland biodiversity. Overseas Development Institute Working paper 121.

Bolling, M., & Schulte, A. (1999). Environmental change and pastoral perceptions: Degradation and indigenous knowledge in two African pastoral communities. *Human Ecology, 27*, 493-514.

Bowman, D. J. S. (2002). People and rangeland biodiversity. In Global Rangelands Progress and Prospects, Edited by Grice AC, Hodgkinson KC. CABI Publishers, Wallingford, Oxon 117-129.

Brady, W., Stromberg, M., Aldon, E.F., Bonham, C.D., & Henry, S.H., (1989). Response of a semidesert grassland to 16 years of rest from grazing. *Journal of Range Management 42*, 284–288.

Brevik, E. C., Cerdà, A., Mataix-Solera, J., Pereg, L., Quinton, J. N., Six, J., & Van Oost, K. (2015). The interdisciplinary nature of soil. *Soil, 1,* 117–129. doi: 10.5194/soil-1-117

Brewer, J.S. (1995). The relationship between soil fertility and fire-stimulated floral induction in two populations of grass-leaved golden aster, *Pityopsis graminifolia*. *Oikos, 74,* 45-54.

Callaway, R.M. (1995). Positive interactions among plants. *Botanical Review, 61,* 306–349.

Callaway, R.M., Brooker, R.W., Choler, P., Kikvidze, Z., Lortie, C.J., & Michalet, R. et al. (2002). Positive interactions among alpine plants increase with stress. *Nature, 417,* 844–848.

Carstensen, D.W., Lessard, J. P., Holt B.G., Krabbe Borregaard M., & Rahbek C. (2013). Introducing the biogeographic species pool. *Ecography, 36,* 1310–1318.

Cavalcante, A.C.R., Araújo, J.F., Do, M., Carneiro, S., Souza, H.A., Tonucci, R.G., Rogerio, M.C.P., & Vasconcelos, E.C.G. (2014). Potential use of tropical grass for deferment in Semi-Arid Region. *American Journal of Plant Science, 5,* 907-914.

Central Statistical Authority (CSA). (2007). Ethiopian Statistical Abstract,Central Statistical Authority, Addis Ababa, Ethiopia.

Chase, J. M. (2003). Community assembly: When should history matter? *Oecologia136* (4), 489–498.

Chase, J. M. (2010). Stochastic community assembly causes higher biodiversity in more productive environments. *Science 328*, 1388–1391.

Chatterjee, B. N., & P. K. Das. (1989)**.** *Forage Crop Production - Principles and Practices*. Oxford and IBH Pub. Co. Pvt. Ltd. New Delhi. 450p.

Chen, J., & Tang, H. (2016). Effect of grazing exclusion on vegetationcharacteristics and soil organic carbon of *Leymus chinensis* grassland in Northern China. *J. 8*, 56. Doi: 10.3390/su8010056

Chen, Y.P., Li, Y.Q., Zhao, X.Y., Awada, T., Shang, W., & Han, J.J. (2012). Effects of grazing exclusion on soil properties and on ecosystem carbon and nitrogen storage in a sandy rangeland of Inner Mongolia, Northern China. *Environ. Manag. 50*, 622–632.

Cheng, J., Wu, G.L., Zhao, L.P., Li, Y., Li, W., & Cheng, J.M. (2011). Cumulative effects of 20-year exclusion of livestock grazing on above- and belowground biomass of typical steppe communities in arid areas of the Loess Plateau, China. *Plant Soil Environ. 57,* 40–44.

Chesson, P. (2000). Mechanisms of maintenance of species diversity. *Annual Review of Ecology and Systematics*, 31, 343–366.

Connor, E. F., & Simberloff, D. (1978). Species number and compositional similarity of the Galapagos flora and avifauna. *EcologicalMonographs,48*, 219–248.

Coppock, D.L. (1994). The Borana plateau of southern Ethiopia: synthesis of pastoral research, development and change, 1980-1991. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. p.393.

Coppolillo, P. B. (2000). The landscape ecology of pastoral herding: spatial analysis of land useand livestock production in East Africa. *Human Ecology 28*, 527-560.

Cornell, H. V., & Lawton, J. H. (1992). Species interactions, local and regional processes, and limits to the richness of ecological communities. A theoretical perspective," *Journal of AnimalEcology*, *61*(1), 1–12.

Cornell, H.V., & Harrison, S.P. (2014). What are species pools and when are they important? *Annual Review of Ecology, Evolution,and Systematics, 45*, 45–67.

Corwin, D. L. & Lesch, S. M. (2005). Characterizing soil spatial variability with apparent soil electrical conductivity I. Survey protocols. *Computers and Electrics in Agriculture, 46,* 103-133.

Cossins, N.J. (1983). Production Strategies and Pastoral Man. Pastoral Systems Research in Sub-Saharan Africa. Proceedings of the IDRC/ILCA Workshop held at ILCA, Addis Ababa, Ethiopia, and 21–24.

Courtois, D.R., Perryman, B.L., Hussein, H.S. (2004).Vegetation change after 65 years of grazing and grazing exclusion. *J. Range Manag. 57*, 574–582.

Cumming, D.H.M. (1982). The influence of large herbivores on savanna structure in Africa. In: Ecology of tropical savanna (Eds: Huntley, J.B. and Walker, B.H.)Springer verlag, Berlin. Pp.219-246.

Dabasso, B H., Oba, G., & Roba, H G. (2012). Livestock-based knowledge of rangeland quality assessment and monitoring at landscape level among Borana herders of northern Kenya. *Pastoralism: Research, Policy andPractice*, 2, 2.

Dabasso, B. H., Taddese, Z., & Hoag, D. (2014). Carbon stocks in semi-arid pastoral ecosystems of northern Kenya. *Pastoralism: Research, Policy and Practice*, *4,* 5.

Dale, V.H., & Beyeler, S.C. (2001). Challenges in the development and use of ecological indicators. *Ecological Indicators, 1,* 3-10.

Davies, J., Poulsen, L., Schulte-Herbrüggen, B., Mackinnon, K., Crawhall, N., Henwood, De Haan, C., Schillhorn van Veen, T., Brandenburg, B., Gauthier, J., le Gall, R., Mearns, F., & Simeon, M. (2001). *Livestock development. Implications for Rural Poverty, the Environmentand Global Food Security*. Washington, D.C., the World Bank.96 pp.

Deleglise, C., Loucougaray, G., Alard, D. (2011). Effects of grazing exclusion on the spatial variability of subalpine plant communities: A multiscale approach. *Basic Appl. Ecol. 12*, 609–619.

Desta, H. (2009). Management for proper range use: Technical bulletin no. 25. ESGPIP (Ethiopia's Sheep and Goat Productivity Improvement Program). Ethiopia.

Dika, G. (2016). The Role of indigenous knowledge in rangeland management in Yabello Woreda, Southern Oromia, Ethiopia. *J Arts Social Sci.*, *7,* 172.

Dika, G. G., Abdulkadir, H. G., & Semegnew, T. F. (2016). Pastoralist perceptions on factors affecting rangeland productivity in Yabello Woreda, Southern Oromia, Ethiopia. *wjpls, Vol. 2, Issue 2,* 239-264.

Diress, T. (1999). Impact of land use on vegetation resource with emphasis on woody vegetation in the semi-arid area of Abala district, North Afar Ethiopia. Msc. Thesis. Haramaya University Ethiopia.

Dohn, J., Dembele, F., Karembe, M., Moustakas, A., Amevor, K.A., & Hanan, N.P. (2013). Tree effects on grass growth in savannas: competition, facilitation and the stress-gradient hypothesis. *Journal of Ecology, 101*, 202–209.

Donahue, R.L., Miller, R.W., & Shickluna, J.C. (1977). Soils: An introduction to soils and plant growth. Prentice-Hall, Upper Saddle River.

Drake, J. A. (1991). Community-assembly mechanics and the structure of an experimental species ensemble. *The American Naturalist 137*, 1–26.

Du Preez, C.C., & Snyman, H.A. (2003). Soil organic matter changes following rangeland degradation in a semi-arid South Africa. Proceedings of the VII International Rangeland Congress, Durban, South Africa, Pp. 476-478.

Dudal, R., & Deckers, J. (1993). Soil organic matter in relation to soil productivity. In: Mulongoy K. and Merckx R. (Eds.), Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. John Wiley and Son, West Sussex, United Kingdom.

El-Beheiry, M. A. H. (2009). Nutritive evaluation of two *Acacia* populations in Southwestern Saudi Arabia. *Journal of Applied Sciences Research, 5*(8), 1030-1039.

Endalew, B. A., Adgo, E., & Argaw, M. (2014). Impact of land use types on soil acidity in the highlands of Ethiopia: The case of Fagetalekoma district. *Academia Journal of Environmental Sciences, 2*(8), 124-132.

Ethiopia Agricultural research Organization (EARO). (2002). National pastoral and agro-pastoral research planning document. Addis Ababa, Ethiopia. p.51.

Ethiopian Agricultural Research Organization (EARO). (2000). National small ruminants research strategy document. EARO, Addis Ababa, Ethiopia.

Fall, D., Diouf, D., Neyra, M., Diouf, O., & Diallo N. (2009). Physiological and biochemical responses of *Acacia seyal* (Del.) seedlings under salt stress conditions. *Journal of Plant Nutrition*, *32*, 1122-1136.

Floyd, M.L., Fleischner, T.L., Hanna, D., & Whitefield, P., (2003). Effects of historic livestock grazing on vegetation at Chaco Culture National Historic Park, New Mexico. *Conservation Biology 17*, 1703–1711.

Food and Agriculture Organization (FAO). (2004). Carbon sequestration in dryland soils. World Soils Resources Reports 102, Rome.

Food and Agriculture Organization (FAO). (2005). Global Forest Resources Assessment. Rome.

Food and Agriculture Organization (FAO/LEAD)**. (**1995) World livestock production systems – Current status, issues and trends. FAO Animal Production and Health Paper, No. 127.

Food and Agriculture Organization (FAO/LEAD). (2006). *Livestock's long shadow*. Environmental issues and options. Rome.

Food and Agriculture Organization and the United Nations Development Program (FAO/UNDP) (1984). Geomorphology and soils of Ethiopia. Assistance to Land use Planning and regulatory Department, Ministry of Agriculture. Addis Ababa, Ethiopia.

Francesco, de B., Sandra L., S é bastien, L., Cécile, H., Albert, I. B., Florent, M., & Wilfried T. (2013). Hierarchical effects of environmental filters on the functional structure of plant communities: a case study in the French Alps. *Ecography 36*, 393–402. doi: 10.1111/j.1600-0587.2012.07438

Fratkin, E. (2003). East African pastoralism in transition: Massi, Boran and Rendille cases African Studies. *Review 44*, 1-25.

Friedel, M.H., Lay cock, W.A. & Basin,G-N, (2000). Assessing rangelands additions and trend.PP 227-262. In Mannetie, K't and R.M Jones (eds.) filed and laboratory methods for grass land and animals production research CABI publishing. Wallingford, UK

Fukami, T. (2005). Integrating internal and external dispersal in metacommunity assembly: pre-iminary theoretical analyses. *Ecological Research 20*, 623–631.

Fukami, T., & Nakajima, M. (2013). Complex plant-soil interactions enhance plant species diversity by delaying community convergence. *Journal of Ecology 101*, 316–324.

Fukami, T., & Nakajima, M. (2015). Historical contingency in community assembly: Integrating niches, species pools, and priority effects. *Annual Review of Ecology Evolution and Systematics 46,* 1–23.

Gamoun, M. (2014). Grazing intensity effects on the vegetation in desertrangelands of Southern Tunisia. *J Arid Land 6(*3), 324–333.

Gamoun, M., Tarhouni, M., & Ouled Belgacem, A. (2011). Response of different arid rangelands to protection and drought. *Arid Land Research and Management, 25,* 372–378.

Ganya, C., Haro, G. O., & G. Borrini-Feyerabend. (2004). Conservation of dryland biodiversity by mobile indigenous people the Case of the Gabbra of Northern Kenya. *Policy Matters. 13,* 61-71.

Geissen, V., Sánchez-Hernández, R., Kampichler, C., Ramos-Reyes, R., Sepulveda-Lozada, A., Ochoa-Goana, S., de Jong, B.H.J., Huerta-Lwanga, E., & Hernández-Daumas, S. (2009). Effects of land-use change on some properties of tropical soils - An example from Southeast Mexico. *Geoderma, 151,* 87-97.

Gemedo- Dalle, T., Isselstein, J., & Maass, B. L. (2006). Indigenous ecological knowledge of Borana pastoralists in southern Ethiopia and current challenges. *International Journal of Sustainable Development & WorldEcology, 13*, 113-130.

Gezu, B. (2011). Assessment of pastoralists' views on enclosures in Shinille and Dollo. Presentation for PLI Policy. Project NRM Review Workshop, Jijiga, November 2011.Gohl, B. (1981). Tropical feeds. Feed information summary and nutritive values. FAO, Animal Production and Health series 12. FAO, Rome.

Gomes, N. (2006). Access to water, pastoral resource management and pastoralists' livelihoods: Lessons learned from water development in selected areas of Eastern Africa (Kenya, Ethiopia, and Somalia*)*. LSP Working Paper 26, Food andAgriculture Organisation of the United Nations, Rome.

Götzenberger, L., de Bello, F., Bråthen, K. A., Davison, J., Dubuis, A., Guisan, A., Lepš, J., Lindborg, R., Moora, M., Pärtel, M., Pellissier, L., Pottier, J.,Vittoz, P., Zobel, K., & Zobel M. (2012). Ecological assembly rules in plant communities – approaches, patterns and prospects. *Biological Reviews, 87,* 111–127.

Grace, J., San Jose, J., Meir, P., Miranda, H., & Montes, R. (2006). Productivity and carbon fluxes of tropical savannas. *J.Biogeogr. 33*, 387–400.

Graham, O. (1988). Enclosure of the east African rangelands: Recent trends and their impact. ODI Pastoral Development Network, Paper 25a.

Grice, A.C., & Hodgkinson, K.C. (2002). Global rangelands, progress and prospects. CABI Publishing, Wallingford, UK.

Grover, S. P. P., Livesley, S. J., Hutley, L. B., Jamali, H., Fest, B., Beringer, J. Butterbach-Bahl, K., & Arndt, S. K. (2011). Land use change and impact on greenhouse gas exchange in north Australian savanna soils. *Biogeosciences Discussions 8,* 9087-9123.

Hagos, M. G., & Smit, G. N. (2005). Soil enrichment by *Acacia mellifera* subsp. *detinens* on nutrient poor sandy soil in a semi-arid southern African savanna. *J. Arid Environ. 61*, 47-59.

Hangsheng, L., Dan, W., Jay, B., & Larry, W. (2005). Assessment of soil spatial variability at multiple scales. *Ecological Modelling*, *182*, 271-290.

Hanke, W., Thomas, M., Svenja, T., Heidi, M., & Jennifer, K. (2014). The impact of livestock grazing on plant diversity. 64(06), 214-223.

Hay, I. (2010). Qualitative research methods in human Geography, Canada, Oxford University Press.

Helland, J. (1997). Development issues and challenges for the future in Borana. *Report prepared for Norwegian ChurchAid, Ethiopia.*

Herrera, G., Arreola, Y., Herrera, B. G., Reyes, R., & Dendoovena, L. (2007). Mesquite (Prosopis juliflora (Sw.) DC.), huisache (Acacia farnesiana (L.) Willd.) and catclaw (Mimosa biuncifera Benth.) and their effect on dynamics of carbon and nitrogen in soils of the semi-arid highlands of Durango Mexico. *J. Arid Environ. 69*, 583–598.

Holechek, J. L., Pieper, R. D., & Herba, C. H. (1998). *Range management: Principles and Practices.* (3rd Edition). Prentice Hall, Upper Saddle River, New Jersey, 07458.

Holmgren, M., Scheffer, M., & Huston, M.A. (1997). The interplay of facilitation and competition in plant communities. *Ecology, 78*, 1966–1975.

Hoshino, A., Yoshihara, Y., Sasaki, T., Okayasu, T., Jamsran, U., Okuro, T., & Takeuchi, K. (2009). Comparison of vegetation changes along grazing gradients with different numbers of livestock. *J. Arid. Environ. 73*, 687-690.

Hussain, F., & Durrani, M. J. (2008). Mineral composition of some range grasses and shrubs from Harboi rangeland Kalat, Pakistan. *Pakistan Journal of Botany, 40*(6), 2513-2523.

Hussain, F., & Durrani, M. J. (2009). Seasonal availability, palatability and animal preferences of forage plants in Harboi arid range land, Kalat, Pakistan. *Pakistan Journal of Botany*, *41* (2), 539-554.

Ibrahim, M. A. (2016). Impact of enclosure on plant species composition and biomass production in Ewa Woreda of Afar Region State, Ethiopia. *J Biodiversity Endanger Species 4*, 157. doi:10.4172/2332-2543.1000157

IIED/WWF. (2007). Climate, Carbon, Conservation and Communities. Briefing, UK (available at http://www.iied.org/pubs/pdfs/17011IIED.pdf).

Jamil, A., Ahmad M. A., & Ghasem A. T. (2011). Relationship between plants evening and soil properties in the rangeland, Lar National Park, Iran. *African Journal of Agricultural Research6*(24), 5551-5557.

Johnson, K. G., Vogt K. A., Clark H. J., Schmitz O. J., & Vogt D. J. (1996). Biodiversity and the productivity and stability of ecosystems. *Trends in Ecology and Evolution 11*, 372–377.

Jonathan, B. & Walter, J.(2013). Spatial Scaling of Functional Structure in Bird and Mammal Assemblages vol. 181, no. 4 the American naturalist. Online enhancements: appendixes. Dryad data: http://dx.doi.org/10.5061/dryad.78sr6.

Jones, C. (2006). Grazing Management for Healthy Soils. March 24, 2006 (available at http:// grazingmanagement.blogspot.com/).

Kaimba, G. K., Njehia B. K. and Guliye A. Y. (2011). Effects of cattle rustling and household characteristics on migration decisions and herd size amongst pastoralists in Baringo District, Kenya. *Pastoralism: Research, Policy and Practice, 1*, 18.

Kamara, A., Kirk, M., & Swallow, B. (2004). Property rights and land use change: Implications for sustainable resource management in Borana, southern Ethiopia. *Journal of Sustainable Agriculture*, *25*, 45-61.

Kassahun, A., Snyman, H. A. & Smit, G. N. (2008), Impact of rangeland degradation on the pastoral production systems, livelihoods and perceptions of the Somali pastoralists in Eastern Ethiopia. *Journal ofArid Environments*, (72), 1265–1281

Kavianpoor, H., Esmali, O. A., Jafarian, J. Z., & Kavian, A. (2012). Spatial variability of some chemical and physical soil properties in Nesho mountainous rangelands. *American Journal of Environmental Engineering*, *2*(1), 34-44.

Keddy, P.A. (1992) Assembly and response rules - two goals for predictive community ecology. *Journal of Vegetation* Science 3, 157-164.

Keesstra, S. D., Geissen, V., van Schaik, L., Mosse, K., & Piiranen, S. (2012). Soil as a filter for groundwater quality, Current Opinions in Environmental Sustainability, 4, 507–516,

Kgosikoma, O. E. (2011). Understanding the savanna dynamics in relation to rangeland management systems and environmental conditions in semi-arid Botswana. PhD Thesis, University of Edinburgh.

Kgosikoma, O. E., Mojeremane, W. & Harvie, B. A. (2012). Pastoralists' perception and ecological knowledge on savanna ecosystem dynamics in semi-arid Botswana. *Ecology and Society*, *17* (4), 27.

Kgosikoma, O. E., Mojeremane, W., & Harvie, B. A. (2013). Grazing management systems and their effects on savanna ecosystem dynamics: A review. *Journal of Ecology and the Natural Environment*, *5* (6), 88-94.

Kökten, K., Kaplan, M., Hatipoğlu, R., Saruhan, V., & Çınar, S. (2012). Nutritive value of Mediterranean shrubs. *Journal of Animal and Plant Sciences*, *22* (1), 188-194.

Kovacs, J. M. (2000). Perceptions of environmental change in a tropical coastal wetland. *LandDegradation & Development 11*, 209-220.

Kreutzmann, H., Yang Yong, Richter, J. (2011). Pastoralism and rangeland management on the Tibetan Plateau in the context of climate and global change. Bonn: GIZ.

Ladio, A. H., & Lozada, M. (2009). Human ecology, ethnobotany and traditional practices in rural populations inhabiting the Monte region: resilience and ecological knowledge. *Journal of Arid Environment*, *73,* 222-227.

Laidlaw, A.S. (2005). The relationship between tiller appearance in spring and contribution of dry matter yield in perennial ryegrass (Lolium perenne L.) cultivars differing in heading date. *Grass and Forage Science, 60,* 200-209.

Lars, A. B., & Catherine M. M. (2008). Trait-based filtering of the regional species pool to guide understory plant reintroductions in Midwestern Oak Savannas, U.S.A. *Restoration Ecology, 16(*2), 290–304

Laughlin, D. C., & Abella, S. R. (2007). Abiotic and biotic factors explain independent gradients of plant community composition in ponderosa pine forests. *Ecological Modelling*, *205,* 231-240.

League for Pastoral Peoples and Endogenous Development (Germany) and Lokhit Pashu-Palak Sansthan (India)(LPPED and LPPS). 2005. The Role of Pastoralism in the conservation of dryland ecosystems. Accessed at: http://www.drynet.org/uploaded_files/Enhancing_the_role_of_pastoralism_in_the_conservation 1.ppt.

Leakey, R. R. B. (2002). The domestication of indigenous trees as the basis of a strategy for sustainable land use. TWNSO African Regional Workshop: Promoting best practice of conservation and sustainable use of biodiversity of Global Significant in Arid and Semi-arid Zones, Muscat, Oman.

Lessard, J. P., Belmaker, J., Myers, J. A., Chase, J. M., & Rahbek, C. (2012). Inferring local ecological processes amid species pool influences. *Trends in Ecology and Evolution*, *27,* 600–607.

Li, X. G., Li, F. M., Zed, R., Zhan, Z. Y., & Singh, B. (2007). Soil physical properties and their relations to organic carbon pools as affected by land use in an alpine pastureland. *Geoderma*, *139,* 98-105.

Li, X. L., Gao, J., Brierley, G., Qiao, Y. M., Zhang, J., & Yang, Y. W. (2013). Rangeland degradation on the Qinghai-Tibet plateau: Implications for Rehabilitation. *Land Degrad. Dev., 24,* 72–80. doi:10.1002/ldr.1108.

Ludwig, F., Dawson, T. E., Prins, H. H. T., Berendse, F., & de Kroon, H. (2004). Below-ground competition between trees and grasses may overwhelm the facilitative effects of hydraulic lift. *Ecology Letters, 7,* 623–631.

Lund, H. G. (2007). Accounting for the World's Rangelands. *Rangelands, 29,* 1, 3-10.

Lunt, I.D., Eldridge, D.J., Morgan, J.W., & Witt, G. B. (2007). A framework to predict the effects of livestock grazing and grazing exclusion on conservation values in natural ecosystems in Australia. *Aust. J. Bot., 55,* 401–415.

Lykke, A. M., Kristensen, M. K., & Ganaba, S. (2004). Valuation of local use and dynamics of woody species in the Sahel. *Biodiversity and Conservation*, *13,* 1961-1990.

MacArthur, R. H., & Wilson, E. O. (1967). *The theory of island biogeography*. Princeton University Press, Princeton, USA.

Mahgoub, H. G. Arabi, N. Y., & Mubarak, A. R. (2016). Changes in physico-chemical properties of a desert soil under different long-term land use systems. *Academia Journal of Agricultural Research 4*(3), 105-112,

Mapinduzi, A. L., Oba, G., Weladjii, R. B., & Colman, J. E. (2003). Use of indigenous ecological knowledge of the Maasai pastoralists for assessing rangeland biodiversity in Tanzania. *African Journal of Ecology*, *41,* 329-336.

Markakis, J. (1993). *In*: conflict and the decline of pastoralism in the Horn of Africa. Macmillan, London.

Marteinsdóttir, B., & Eriksson, O. (2014a). Plant community assembly in semi-natural grasslands and ex-arable fields: a trait based approach. *Journal of Vegetation Science 25*, 77-87.

Marteinsdóttir, B., & Eriksson, O. (2014b). Trait-based filtering from the regional species pool into local grassland communities. *Journal of Plant Ecology, 7(*4), 347–355 doi:10.1093/jpe/rtt032.

Martin, L. M., & Wilsey, B. J. (2012). Assembly history alters alpha and beta diversity, exotic native proportions and functioning of restored prairie plant communities. *Journal of Applied Ecology 49*, 1436–1445.

Masuka, B., Araus, J. L., Das, B., Sonder, K., & Cairns, J. E. (2012). Phenotyping for abiotic stress tolerance in Maize. *Journal of integrative plant biology, 54*(4), 238-249.

McAllan, A., (1993). Acacia seyal: a handbook for extension workers. Bangor, UK: School of Agricultural and Forest Sciences. University of Wales.

McNaughton, S.J. (1979). Grazing as an optimization process: grass-ungulate relationships in the Serengeti. *Am. Nat., 113*, 691–703.

McPeak, J. G., Barrett, C. B. (2001). Differential risk exposure and stochastic poverty traps among east African pastoralists. *American Journal of Agricultural Economics83*,674–679.

Mcsherry, M. E., Ritchie, M. E. (2013). Effects of grazing on grassland soil carbon: A global review. *Globl. Chang. Biol., 19*, 1347–1357.

Mekuria, W., & Aynekulu, E. (2013). Enclosure land management for restoration of the soils in degraded communal grazing lands in Northern Ethiopia. *Land Degrad. Dev., 24,* 528–538.

Mganga, K. Z., Musimba, N. K. R., Nyariki, D. M., Nyangito, M. M., & Mwang'ombe, A. W. (2013). The choice of grass species to combat desertification in semi-arid Kenyan rangelands is greatly influenced by their forage value for livestock. Grass and Forage Science. http://onlinelibrary.wiley.

Mittelbach, G. G., & Schemske D. W. (2015). Ecological and evolutionary perspectives on community assembly. *Trends in Ecology & Evolution 30*, 241–247.

Mohammadi, J., & Raeisi G. F. (2004). Fractal description of the impact of long-term grazing exclusion on spatial variability of some soil chemical properties. *JWSS - Isfahan University of Technology*, *7* (4): 25-37.

Mortimore, M. (2009). *Dryland Opportunities: New paradigm for people, ecosystems and development*. New York/Gland, Switzerland/London: UNDP/IUCN/IIED.

Mouat, D., Lancaster, J., Wade, T., Wickham, J. Fox, C., Kerner, W., & Ball, T. (1997). Desertification evaluated using an integrated environmental assessment model. *Environmental Monitoring and Assessment*, *48*, 139-156.

Moussa, A. S., Van Rensburg, L., Kellner, K., & Bationo, A. (2008). Soil indicators of rangeland degradation in a semi-arid communal district in South Africa. *Fut Drylands*, 383-393.

Mureithi, S. M., Verdoodt, A., Gachene, C. K. K., Njoka, J. T., Wasonga, V. O., de Neve, S., Meyerhoff, E., & Van Ranst, E. (2014). Impact of enclosure management on soil properties and microbial biomass in a restored semi-arid rangeland, Kenya. *Journal of Arid Land*,*6*(5): 561-570.

Nandwa, S. M. (2001). Soil organic carbon (SOC) management for sustainable productivity of cropping and agro-forestry systems in Eastern and Southern Africa. *Nutrient Cycling in Agroecosystems, 61,* 143-158.

National Herbarium of Floras and Faunas of Ethiopia (NHEFF). (1987). Guidelines for field assessment and sampling techniques of plant communities in Ethiopia. Addis Ababa University. Ethiopia.

Neely, C., & Hatfield, R. **(**2007). Livestock Systems. *In* Scherr, S. and J. McNeely, eds. *Farming with Nature*. Washington, D.C., Island Press. 296 pp.

Neely, C., Bunning, S., & Wilkes, A. (2009). Review of evidence on drylands pastoral systems and climate change. Implications and opportunities for mitigation and adaptation, in land and water discussion paper 8. FAO, Rome, P.39.

Niamir-Fuller, M. (1999). Managing mobility in African rangelands: The legitimization oftranshumance. London, UK, Intermediate Technology Publications Ltd. 240 pp.

Nobel, I. R., & Slatyer, R. O. (1977). Post-fire succession of plants in Mediterranean ecosystems. In: Mooney HA, Conrad CE, editors. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems. California: *Palo Alto,* 27–36.

Noble, A. D., Randall, P. J. (1999). Alkalinity effects of different tree litters incubated in an acid soil of NSW, Australia. *Agroforest. Syst.*, *46*, 147-160.

Noellemeyer, E., Quiroga, A. R., & Estelrich, D. (2006). Soil quality in three range soils of the semi-arid Pampa of Argentina. *Journal of Arid Environments*, *65*, 142-155.

Nori, M. (2007). Mobile livelihoods, patchy resources & shifting rights: approaching pastoral territories. International Land Coalition, Rome

Nori, M., Taylor, M., & Sensi, A. (2008). Browsing on fences. Pastoral land rights, livelihoods and adaptation to climate change. IIED (International Institute for Environment and Development), Issue paper no. 148.

Notenbaert, A. M. O., Davies, J., De Leeuw, J., Said, M., Herrero, M., Manzano, P., Waithaka, M., Aboud A., & Omondi, S. (2012). Policies in support of pastoralism and biodiversity in the heterogeneous drylands of East Africa. *Pastoralism: Research,Policy and Practice 2,* 14.

Nuray-Müftüoğlu, M., & Ahmet Gökkuş. (2016). Effects of different shrubby rangeland reclamation practices on some of soil characteristics. *Türk Tarım ve Doğa Bilimleri Dergisi 3*(1), 90-97.

Oba, G. (1994). The role of indigenous range management knowledge for desertification control in Northern Kenya. Research Report No.4 .EPOS, Uppsala University.

Oba, G. (1998). Assessments of indigenous range management knowledge of the Borana pastoralists in southern Ethiopia. Borana Lowland PastoralDevelopment Program/GTZ, Consultancy paper, Negelle/Borana May1998. pp. 97.

Oba, G. (2001). The effect of multiple droughts on cattle in Obbu, Northern Kenya. *Journal of Arid Environments 49,* 375-386.

Oba, G. (2012). Harnessing pastoralists' indigenous knowledge for rangeland management: three African case studies, Pastoralism: Research, Policy and Practice, 2. doi:10.1186/2041-7136-2-1.

Oba, G., & Kaitira, L. M. (2006). Herder knowledge of landscape assessments in arid rangelands in northern Tanzania. *Journal of Arid Environment, 66,* 168-186.

Oba, G., & Kotile, D. G. (2001). Assessments of landscape level degradation in southern Ethiopia: Pastoralists vs ecologists. *Land Degrad. Dev., 12,* 461–475.

Oba, G., & Kotile, D. G., (2001). Assessments of landscape level degradation in southern Ethiopia: Pastoralists versus ecologists. *Land Degradationand Development*, *12,* 461-475.

Oba, G., Post, E., Syvertsen, P. O., & Stenseth, N. C. (2000). Bush cover and range condition assessments in relation to landscape and grazing in southern Ethiopia. *LandscapeEcology 15,* 535-546.

O'Connor, T. G., & Pickett, G. A., (1992). The influence of grazing on seed production and seed banks of some African savanna grasslands. *J. Appl. Ecol. 29,* 247e260.

O'Connor, T.G. (1991). Local extinction in perennial grasslands: a life-history approach. Amer. *Nat. 137,* 753e773.

O'Connor, T.G. (1996). Hierarchical control over seedling recruitment of the bunch grass *Themeda triandra* in a semi-arid savanna. *J. Appl. Ecol. 33,* 1094e1106.

Okalebo, J. R., Gathua, K. W., & Woomer, P. L. (2002). Laboratory methods of soil and plant analysis: A Working Manual. TSBF Program UNESCO – ROSTA *Soil Science Society of Eastern Africa technical Publication* No. 1. Marvel EPZ Ltd., Nairobi, Kenya.

Onatibia, G. R., Aguiar, M.R., & Semmartin, M. (2015). Are there any trade-offs between forage provision and the ecosystem service of C and N storage in arid rangelands? *Ecol. Eng. 77,* 26–32.

Palpurina, S. and Wager,V., von Wehrden, H. et al. (2017).The relationship between plant species richness and soil pH vanishes with increasing aridity across Eurasian dry grassland. Global Ecology and Biogeography 26 (4): 425 – 434.

Panchal, N.S. and Pandy, AN, 2002. Study on soil properties and their influences on vegetation in western region of Gujarat state in India. 12th ISCO Conference, Beijing 2002: 610 – 615.

Pastoralist Forum Ethiopia (PFE), IIRR (International Institute of Rural Reconstruction) and DF (The Development Fund) (2010). Pastoralism and Land: Land tenure, administration and use in pastoral areas of Ethiopia.

Pearson, D. E., Icasatti, N. S., Hierro, J. L., & Bird, B. J. (2014). Are local filters blind to provenance? Ant seed predation suppresses exotic plants more than natives. *PLoS ONE 9*(8). doi:10.1371/journal.pone.0103824.

Pellant, M., Shover, P., Pyke, D., & Herrick, J. E. (2005). Interpreting indicators of rangeland health. Version 4. Interagency Technical. Reference 1734-6, Bureau of Land Management, Denver, Colorado, USA.

Pierotti, R., & Wildcat, D. (2000). Traditional ecological knowledge: the third alternative (Commentary). *Ecological Applications 10*, 1333-1340.Pilania, P.K. and Panchal, N.S., 2014. Soil and plant relation at little Rann of Kutch in Mallya Teshsil of Gujarat in western India. *International Journal of Advanced Research, 2* (7), 1-10.Pilania, P.K. and Panchal, N.S., 2016. Influence of soil properties on plant density and species richness of saline desert. *Anales de Biologia, 38*, 81 – 90.

Piñeiro, G., Parnelo, J., Osterheld, M., & Jobbagy, E. (2010). Pathways of grazing effects on soil carbon and nitrogen. *Range Ecology and Management*, *63* (1), 109-119.

Pyke, D. A., Herrick, J. E., Shaver, P., & Pellant, M. (2002). Rangeland health attributes and indicators for qualitative assessment. *Journal of Range Management, 55:* 584- 597.

Qiu, L., Wei, X., Zhang, X., & Cheng, J. (2013). Ecosystem carbon and nitrogen accumulation after grazing exclusion in semiarid grassland. *PLoS ONE 8*.

Raddad, E. Y. (2006). Analysis of systems based on *Acacia senegal* in the Blue Nile Region, Sudan. PhD Dissertation, University of Helsinki, Khartoum, Sudan.

Rahim, I., & Sultan J. I., Yaqoob M., Nawaz H., Javed I., & Hameed M. (2008). Mineral profile, palatability and digestibility of marginal land grasses of Trans-Himalayan grasslands of Pakistan. *Pakistan Journal of Botany*, *40* (1), 237-248.

Rasool, F., Zahoor, H. K., Muhammad, I., Zafar, H., Khalid M. K., Muhammad S.S., Muhammad F., & Muhammad B. (2013). Assessment of nutritional status in selected indigenous and exotic rangeland grasses. *World Applied Sciences Journal*, *21* (5), 795-801.

Reed, M. S., Dougill, A. J., & Taylor, M. J. (2007). Integrating local and scientific knowledge for adaptation to land degradation: Kalahari rangeland management options. *Land Degrad. Dev., 18*, 249– 268, doi:10.1002/ldr.777,

Rees, M. (1996). Evolutionary ecology of seed dormancy and seed size. Philosophical Transactions of the Royal Society of London, *Series B-Biological Sciences 251*, 1299-1308.

Regional Program of Plan to Adapt to Climate Change (RPPACC). (2011): Climate Change: Impacts, Vulnerabilities & Adaptation Strategies in Somali Region, Jigjiga, Ethiopia.

Rezaei, A. S., & Gilkes R. J. (2005). The effects of landscape attributes and plant community on soil chemical properties in rangelands. *Geodema*, *125*, 167- 176.

Ricklefs, R.E. (1987). Community diversity – relative roles of local and regional processes. *Science*, *235*, 167–171.

Roba, H., & Oba, G. (2009). Efficacy of integrating herder knowledge and ecological methods for monitoring rangeland degradation in northern Kenya. *Human Ecology,* 37, 589–612.

Rogerio, C., Ana L. B. H., & Quirijn de, J. L. (2006). Spatio-temporal variability of soil water tension in a tropical soil in Brazil, *Geoderma*, *133,* 231-243.

Rong, Y, Yuan, F., Ma, L. (2014). Effectiveness of exclosures for restoring soils and vegetation degraded by overgrazing in the Junggar Basin, China. *Grassland Sci. 60,* 118–124.

Salem, B. (2007). Sustainable Management of the North African Marginal Drylands. Human Development Report Office, Occasional paper.

Sandford, S. (1983). Management of pastoral development in the Third World, Overseas Development Institute, London.

Sandford, S., & Habtu, Y. (2000). Report of the pastoral appraisal team one emergency responseinterventions in pastoral areas of Ethiopia.UK Department for International Development, London. Available at http://repository.forcedmigration.org/show_metadata. jsp?pid=fmo:5300

Sayre, N. F., McAllister, R. R., Bestelmeyer, B. T., Moritz, M., & Turner, M. D. (2013). Earth Stewardship of rangelands: coping with ecological, economic, and political marginality. *Frontiers in Ecology and the Environment, 11(7),* 348-354.

Schoenbach, P., Wan, H., Gierus, M., Bai, Y., Mueller, K., Lin, L., Susenbeth, A., & Taube F. (2011). Grassland responses to grazing: Effects of grazing intensity and management system in an Inner Mongolian steppe ecosystem. *Plant Soil 340,* 103–115.

Schuman, G., Janzen, H., & Herrick, J. (2002). Soil carbon dynamics and potential carbon sequestration by rangelands. *Environmental Pollution*, *116,* 391-396.

Scoones, I. (1995). Living with uncertainty: New directions for pastoral development in Africa. London, and Intermediate Technology Press. 210 pp.Sebastia, M. T., Marks, E. &Poch,

RM. (2008). Soil carbon and plant diversity distribution at farm level in the savannah region of North Togo (West Africa). *Biogeoscience Discussions 5,* 1 – 21.

Secretariat of the Convention on Biological Diversity (SCBD), (2004). The Ecosystem Approach. Accessed at: http://www.cbd.int/guidelines/.

Secretariat of the Convention on Biological Diversity (SCBD). (2010). *Pastoralism, Nature Conservation and Development: A Good Practice Guide*. Montreal, 40 + iii pages.

Sharafatmandrad, M., Sepehry, A., & Barani, H. (2014). Plant species and functional types' diversity in relation to grazing in arid and semi-arid rangelands, Khabr National Park, Iran. *Journal of Rangeland Science, 4,* 203–214.

Shurin, J. B., & Srivastava, D. S. (2005). New perspectives on local and regional diversity: beyond saturation. *Metacommunities* (ed. by M. Holyoak, R. Holt and M. Leibold), pp. 399–417. University of Chicago Press, Chicago.

Shurin, J., B., Amarasekare, J., Chase, R., Holt, M., Hoopes, & Leibold, M., (2004). Alternative stable states and regional community structure. *Journal of Theoretical Biology 227,* 359–368.

Silanikove, N., Gilboa, N., Nir, I., Perevolotzky, A., & Nitsan Z. (1996). Effect of daily supplementation of polyethylene glycol on intake and digestion of tannin-containing leaves (*Quercus calliprinos*, *Pistacia lentiscus* and *Ceratonia siliqua*) by goats. *Journal of Agriculture and Food Chemistry, 44,* 199-205.

Sinclair, A. R. E., Fryxell, J. M. (1985). The Sahel of Africa: ecology of a disaster. *CanadianJournal of Zoology, 63,* 987-994.

Skinner, H. R., & Moore, K. J. (2007). *Growth and development of forage plant.* In: Barnes R.F., Nelson C.J., Moore K.J.,Collins M.: Forages: The Science of Grassland Agriculture. (6th Ed.) Wiley-Blackwell, Ames, USA, 53–66.

Slatkin, M. (1974). Competition and regional coexistence. *Ecology 55*, 128–134.

Solomon, G., & Yayneshet T. (2014). Rangeland vegetation responses to settlement in the semi-arid rangelands of northern Ethiopia. *Scholarly Journal of Agricultural Science, 4(12),* 587-595.

Solomon, T. B., Snyman H. A., & Smit, G. N. (2007). Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management, 82,*481-494.

Somali Region Pastoral and Agro-Pastoral Research Institute (SoRPARI). (2011). Range and forestry biophysical business process, project proposal on establishment of area enclosures to rehabilitate and improve degraded rangelands at Arara, Gashamo, Adadle, Wardher and Kebridahar Woredas of Somali Regional State for R&D.

Somali Region Pastoral and Agro-Pastoral Research Institute (SoRPARI). (2005): Rangeland management and ecology research strategy document of Somali region, Ethiopia.

Southern Eastern Rangeland Development Project of Ethiopia (SERP) (1990): Assessment of drought impact in Hararghe Province of Eastern Ethiopia, Jigjiga, Ethiopia.

Steffens, M., Kölbl, A., 7 Kögel-Knabner, I. (2009). Alteration of soil organic matter pools and aggregation in semi-arid steppe top soils as driven by organic matter input. *European J. Soil Sci. 60*, 198–212.

Stringer, L.C., Twyman, C., & Thomas, D. S. G. (2007). Combating land degradation through participatory means: The case of Swaziland. *Ambio, 36,* 387-393.

Sugule, J., & Walker, R. (1998). Changing pastoralism in the Ethiopian Somali National Regional State (Region 5), University of Pennsylvania – African Studies Center, UNDP-EUE, Addis Ababa.

Sulieman, H. M., & Ahmed, A. G. M. (2013). Monitoring changes in pastoral resources in eastern Sudan: A synthesis of remote sensing and local knowledge. *Pastoralism: Research, Policy and Practice, 3,* 22.

Sulieman, H. M., Buchroithner, M. F., & Elhag, M. M. (2012). Use of local knowledge for assessing vegetation changes in the southern Gadarif region, Sudan. *African Journal of Ecology, 50* (2), 233-242.

Sutherland, J. P. (1974). Multiple stable points in natural communities. *The American Naturalist 108,* 859–873.

Tache, B. (2010). Participatory impacts assessment of drought reserve areas in Guji and Borana Zones, Oromia Region. Report prepared for Save the Children USA, March 2010, Addis Ababa

Tache, B. (2013). Rangeland enclosures in Southern Oromia, Ethiopia: an innovative response or the erosion of common property resources? *In: Catley, A., Lind., J., and Scoones, I. (Eds). Pastoralism and Development in Africa: Dynamic Change at the Margins, Pathways to sustainability, Routlege***,** *37* - 46.

Tache, B., & G. Oba, (2010).Is poverty driving Borana herders in Southern Ethiopia to Crop Cultivation, *Human Ecology, DOI 10.1007/s10745-010-9349-8.*

Talasan Consultancy PLI (TCC) (2009). The impact of enclosures on access to rangelands: Findings of a cross-border (Somaliland and Somali Region) study commissioned by Oxfam *GB.* Oxfam GB.

Tanentzap, A. J., Coomes, D. A.(2012). Carbon storage in terrestrial ecosystems: Do browsing and grazing herbivores matter? *Biol. Rev., 87,* 72–94.

Taneyhill, D. E. (2000). Metapopulation dynamics of multiple species: The geometry of competition in a fragmented habitat. *Ecological Monographs 70,* 495–516.

Tang, C., & Yu, Q. (1999). Impact of chemical composition of legume residues and initial soil pH on pH change of a soil after residue incorporation. *Plant Soil215,* 29-38.

Tefera, S., Snyman, H. A., & Smit, G. N. (2007). Rangeland dynamics in southern Ethiopia: (1) Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. *Journal of Environmental Management, 85,* 429-442.

Teka, H., Madakadze, I. C., Angassa, A., & Hassen, A. (2012). Effect of seasonal variation on the nutritional quality of key herbaceous species in semi-arid areas of Borana, Ethiopia. *Indian Journal of Animal Nutrition,29*(4), 324-332.

Teshome, A. (2016). Indigenous ecological knowledge and pastoralist perception on rangeland management and degradation in Guji Zone of South Ethiopia. *The Journal of Sustainable Development 15*, 192-218.

Thomas, D. S. G., & Twyman, C. (2004). Good or bad rangeland? Hybrid knowledge, science, and local understandings of vegetation dynamics in the Kalahari. *Land Degradation and Development*, *15*, 215-231.

Thurow, T.L., Blackburn W.H., & Taylor, C.A. (1988). Infiltration and inter-rill erosion responses to selected livestock grazing strategies. Edwards Plateau, Texas. *J. Range Manag*. *41*, 296– 302.

Tiffany, M. E., McDowell, L. R., O'Connor, G. A., Nguyen, H., Martin, F. G., Wilkinson, N. S., & Cardoso, E. C. (2000). Effects of pasture applied bio-solids on forage and soil concentrations over a grazing season in North Florida. I. Macro Minerals, Crude Protein and in Vitro Digestibility. *Communications in Soil Science and Plant Analysis*, *31,* 201-203.

Tilman, D., Wedin, D., & Knops, J. (1996). Productivity and sustainability influenced by biodiversity in grassland ecosystems. *Nature 379*, 718–720.

Tolera, A., Khazal, K., & Ørskov, R. (1997). Nutritive evaluation of some browse species. *Animal Feed Science and Technology*, *67,* 181-195.

Traoré, S., Zerbo, L., Schmidt, M., & Thiombiano, L. (2012). Acacia communities and species responses to soil and climate gradients in the Sudano-Sahelian zone of West Africa. *Journal of Arid Environment, 87,* 144-152.

Turner, N. J., Ignace, B., & Ignace, R. (2000). Traditional ecological knowledge and wisdom of Aboriginal peoples in British Columbia. *Ecological Applications, 10,* 1275–1287.

United Nations Conference on Environment and Development (UNCED) (1992). Managing fragile ecosystems: Combating desertification and drought, Agenda 21. United Nations, New York, NY.

United Nations Convention to Combat Desertification (UNCCD). (2000). Assessment of the status of land degradation in arid, semi-arid and dry sub-humid areas. Bonn.

van der Valk A.G. (1981). Succession in wetlands – a Gleasonian approach. *Ecology*. *62*, 688–96.

Walker, B.H., & Abel, N. (2002). Resilient rangelands-adaptation in complex systems. In:Gunderson, L.H., Holling, C.S. (Eds.), Panarchy, Understanding Transformations in Human and Natural Systems. Island Press, Washington, London.

Wang, C.Y., He, N.P., Zhang, J.J., Lv, Y.L., & Wang, L. (2015). Long-term grazing exclusion improves the composition and stability of soil organic matter in Inner Mongolian grasslands. *PLoS ONE*, 10.

Wang, Y., Zhang, X., & Huang C. (2009). Spatial variability of soil total nitrogen and soil total phosphorus under different land uses in a small watershed on the Loess Plateau, China. *Geoderma,150*: 141- 149.

Weindorf, D. C., & Zhu, Y., (2010). Spatial variability of soil properties at Capulin volcano, New Mexico, USA: Implica-tions for sampling strategy. *Pedosphere*, *20* (2), 185-197.

Wekesa, C., Makenzi, P., Chikamai, B. N., Lelon J. K., Luvanda A. M., & Muga M. (2009). Gum arabic yield in different varieties of *Acacia senegal* (L.) Wild. in Kenya. *African Journal of Plant Science,3*(11): 263-276.

Wiebke, H., Jürgen, B., Niels, D., Norbert J., Ute, S., Dirk, W., & Jürgen D. (2014). The impact of livestock grazing on plant diversity: an analysis across dryland ecosystems and scales in southern Africa. *EcologicalApplications 24*, 1188–1203.

Wiesmeier, M., Steffens, M., Kölbl, A., Kögel-Knabner, I. (2009). Degradation and small-scale spatial homogenization of top soils in intensively-grazed steppes of northern China. *Soil Tillage Res., 104,* 299–310.

Wiesmeier, M., Steffens, M., Mueller, C.W., Kolbl, A., Reszkowska, A., Peth, S., Horn, R., Kogel-Knabner, I. (2012). Aggregate stability and physical protection of soil organic carbon in semi-arid steppe soils. *Eur. J. Soil Sci. 63,* 22–31.

Wilcox, B. P., & Thurow, T. L. (2006). Preface “Emerging issues in rangeland ecohydrology”, *Hydrol. Process. 20,* 3155–3157 151

Wilson, J. R., Deinum, B., & Engels, F. M. (1991). Temperature effects on anatomy and digestibility of leaf and stem of tropical and temperate forage species. *Netherlands Journal of Agricultural Science, 39,* 31–48.

Winn, A. A. (1991). Proximate and ultimate sources of with in individual variation in seed mass in *Prunella vulgaris* (Lamiaceae). *Amer J Bot 78,* 838-844.

Woodward, F.I., & Diament, A. D. (1991). Functional approaches to predicting the ecological effects of global change. *Funct Ecol. 5,* 202–12.

Wulff, R. D. (1986). Seed size variation in *Desmodium paniculatum*: I. Factors affecting seed size. *J Ecol 74,* 87-97.

Yacob, A. (2000). Pastoralism in Ethiopia: the issues of viability. Paper presented at the *NationalConference on Pastoral Development in Ethiopia*, Addis Ababa, and 2 February 2000.

Zhang, D. Y., & Jiang, X. H. (1997). A hypothesis for the origin and maintenance of species diversity within community. *ChineseBiodiversity, 5,* 161–167.

Zhang, Y., Zhao, W. (2015). Vegetation and soil property response of short-time fencing in temperate desert of the Hexi Corridor, northwestern China. *Catena 133,* 43–51.

Zhao, L., Su, J., Wu, G., Gillet, F. (2011). Long-term effects of grazing exclusion on aboveground and belowground plant species diversity in a steppe of the Loess Plateau, China. Plant Ecol. *Evol., 144*, 313–320.

Zhao, Y., Peth, S., Krummelbein, J., Horn, R., Wang, Z., Steffens, M., Hoffmann, C., & Peng, X. (2007). Spatial variability of soil properties affected by grazing intensity in Inner Mongolia grassland. *Ecological Modeling*, *205*, 241-254.

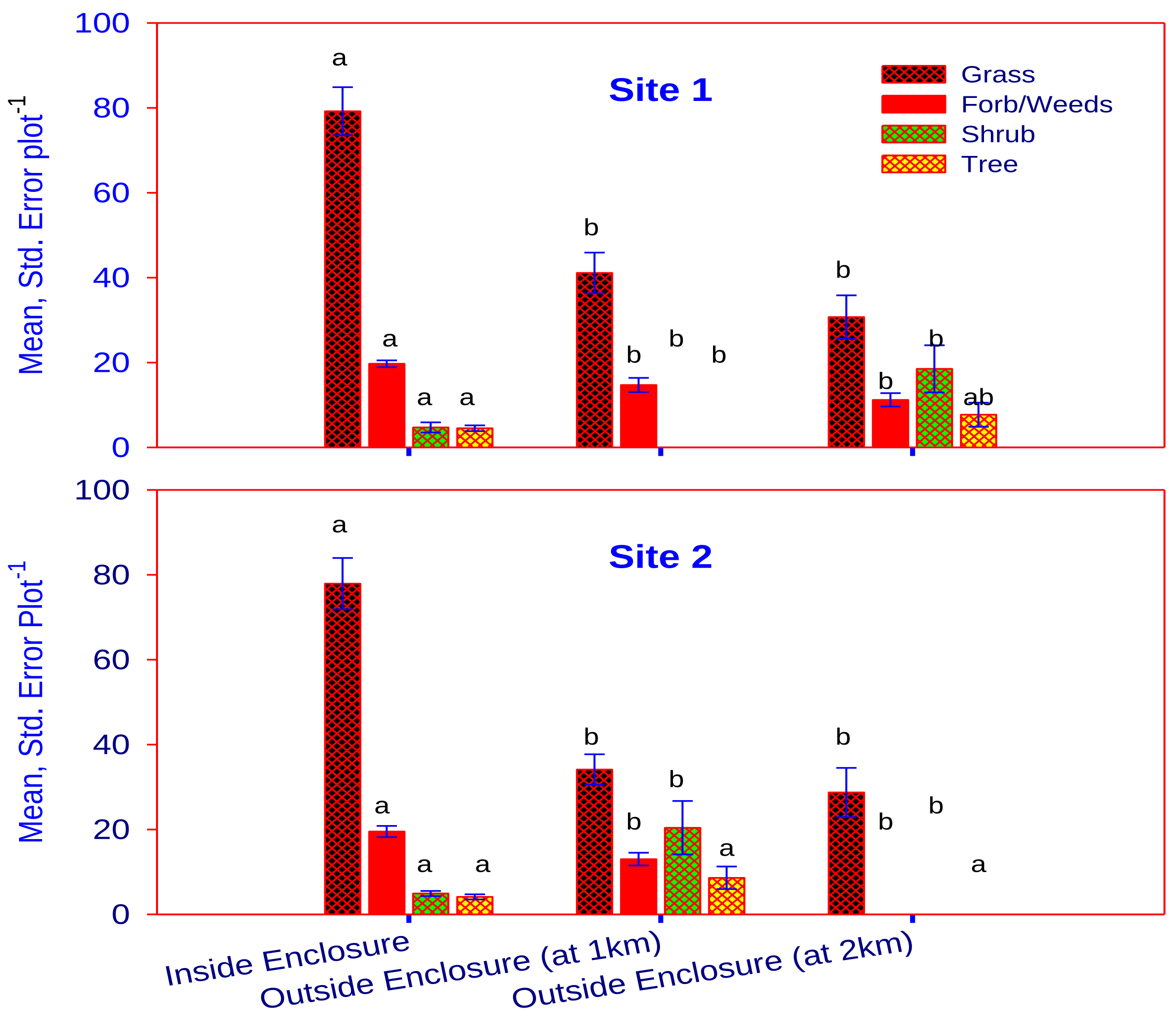
APPENDICES

Appendix A: GPS Coordinates

Appendix A1: GPS coordinates of circular sampling site for inside enclosure, 1km radius and 2km radius of both study sites

	SITE 1						SITE 2					
	GPS		Grass	Forbs/ weeds	Shrub	Tree	GPS		Grass	Forbs/ weeds	Shrub	Tree
TOTAL PLOTS NUMBER			30(150 sub plots)	30(150 sub plots)	30(150 sub plots)	30			30(150 sub plots)	30(150 sub plots)	30(150 sub plots)	30
PLOT SIZE (m^2)	Latitude	Longitude	1x1	1x1	5x5	20x20	Latitude	Longitude	1x1	1x1	5x5	20x20
LOCAL SPECIES POOL(INSIDE ENCLOSURE)	9 40'20"N	41 49'15"E	65	19	5	3	9 42'03"N	41 51'40"E	71	17	2	4
	9 40'22"N	41 49'13"E	85	19	2	3	9 42'04"N	41 51'40"E	75	21	3	6
	9 40'22"N	41 49'11"E	78	21	9	4	9 42'06"N	41 51'39"E	84	20	3	5
	9 40'23"N	41 49'08"E	60	17	12	8	9 42'07"N	41 51'38"E	81	21	6	3
	9 40'19"N	41 49'08"E	108	23	0	3	9 42'04"N	41 51'35"E	124	29	7	7
	9 40'17"N	41 49'09"E	92	24	1	2	9 42'02"N	41 51'36"E	86	19	7	3
	9 40'17"N	41 49'10"E	60	18	7	6	9 42'00"N	41 51'36"E	73	20	6	3
	9 40'17"N	41 49'11"E	57	16	5	8	9 41'58"N	41 51'37"E	62	17	3	6
	9 40'17"N	41 49'13"E	97	21	3	3	9 42'00"N	41 51'39"E	51	13	6	3
	9 40'17"N	41 49'16"E	90	19	3	5	9 42'02"N	41 51'40"E	82	18	6	1
REGIONAL SPECIES POOL (1km FROM ENCLOSURE)	9 40'27"N	41 49'43"E	22	5	8	1	9 41'57"N	41 52'09"E	40	7	7	3
	9 40'46"N	41 49'30"E	43	18	13	6	9 42'16"N	41 52'08"E	45	10	10	3
	9 40'52"N	41 49'09"E	16	9	14	0	9 42'33"N	41 51'52"E	40	8	10	3
	9 40'42"N	41 48'49"E	44	9	14	0	9 42'33"N	41 51'22"E	32	10	38	19
	9 40'14"N	41 48'39"E	39	15	26	20	9 42'08"N	41 51'05"E	22	7	42	22
	9 39'56"N	41 48'49"E	71	18	17	5	9 41'50"N	41 51'08"E	46	11	43	13
	9 39'49"N	41 42'02"E	58	18	31	20	9 41'38"N	41 51'19"E	32	10	2	2
	9 39'47"N	41 49'14"E	51	14	33	23	9 41'33"N	41 51'31"E	36	16	27	18
	9 39'52"N	41 49'29"E	39	13	24	16	9 41'33"N	41 51'46"E	68	22	3	1
	9 40'06"N	41 49'42	54	15	19	11	9 41'41"N	41 52'00"E	45	14	4	2
REGIONAL SPECIES POOL (2km FROM ENCLOSURE)	9 40'35"N	41 50'15"E	57	14	4	0	9 41'50"N	41 52'41"E	39	14	14	3
	9 41'13"N	41 49'50"E	13	6	2	0	9 42'28"N	41 52'39"E	21	10	14	6
	9 41'25"N	41 49'08"E	9	3	2	0	9 43'02"N	41 52'05"E	47	13	10	0
	9 41'05"N	41 48'25"E	15	6	1	0	9 43'02"N	41 51'08"E	6	0	7	0
	9 40' 09"N	41 48'07"E	61	18	14	7	9 42'11"N	41 50'32"E	45	17	42	18
	9 39'32"N	41 48'27"E	51	12	22	14	9 41'35"N	41 50"38"E	66	18	42	17
	9 39'18"N	41 48'53"E	15	10	20	1	9 42'12"N	41 50'58"E	71	22	15	3
	9 39'15"N	41 49'17"E	44	12	46	21	9 41'00"N	41 51'24"E	7	0	8	0
	9 39'25"N	41 49'46"E	54	14	26	12	9 41'01"N	41 51'53"E	6	0	5	0
	9 39'53"N	41 50'12"E	56	16	48	22	9 41'18"N	41 52'24"E	52	18	24	10

Appendix A2:Mean value of grass, forb, shrub and tree at local species pool (inside enclosure), ecological species pool (1km) and regional species pool (at 2km) at site 1 and site 2



Appendix A3: Multiple Comparisons which is illustrated on Figure 6. (1.00-IEUA, 2.00-IEWA, 3.00-OEUA AND 4.00-OEWA)

				Plant height		Tiller number		Seed number		Seed weight	
Dependent Variable				Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.
Aristida kelleri	LSD	1.00	2.00	5.96000*	.000	-1.34000*	.000	-1.50000	.431	-.01220*	.007
			3.00	1.62000*	.029	-2.82000*	.000	12.50000*	.000	.02050*	.000
			4.00	9.02000*	.000	-.28000	.263	17.30000*	.000	.00680	.117
		2.00	1.00	-5.96000*	.000	1.34000*	.000	1.50000	.431	.01220*	.007
			3.00	-4.34000*	.000	-1.48000*	.000	14.00000*	.000	.03270*	.000
			4.00	3.06000*	.000	1.06000*	.000	18.80000*	.000	.01900*	.000
		3.00	1.00	-1.62000*	.029	2.82000*	.000	-12.50000*	.000	-.02050*	.000
			2.00	4.34000*	.000	1.48000*	.000	-14.00000*	.000	-.03270*	.000
			4.00	7.40000*	.000	2.54000*	.000	4.80000*	.015	-.01370*	.003
		4.00	1.00	-9.02000*	.000	.28000	.263	-17.30000*	.000	-.00680	.117
			2.00	-3.06000*	.000	-1.06000*	.000	-18.80000*	.000	-.01900*	.000
			3.00	-7.40000*	.000	-2.54000*	.000	-4.80000*	.015	.01370*	.003
Eragrostis ciliansisi	LSD	1.00	2.00	9.50000*	.000	-.18000	.180	-208.30000*	.000	-.04490*	.003
			3.00	8.92000*	.000	-.24000	.077	170.60000*	.001	.04450*	.003
			4.00	24.66000*	.000	.24000	.077	112.60000*	.018	.06090*	.000
		2.00	1.00	-9.50000*	.000	.18000	.180	208.30000*	.000	.04490*	.003
			3.00	-.58000	.620	-.06000	.652	378.90000*	.000	.08940*	.000
			4.00	15.16000*	.000	.42000*	.003	320.90000*	.000	.10580*	.000
		3.00	1.00	-8.92000*	.000	.24000	.077	-170.60000*	.001	-.04450*	.003
			2.00	.58000	.620	.06000	.652	-378.90000*	.000	-.08940*	.000
			4.00	15.74000*	.000	.48000*	.001	-58.00000	.210	.01640	.254
		4.00	1.00	-24.66000*	.000	-.24000	.077	-112.60000*	.018	-.06090*	.000
			2.00	-15.16000*	.000	-.42000*	.003	-320.90000*	.000	-.10580*	.000
			3.00	-15.74000*	.000	-.48000*	.001	58.00000	.210	-.01640	.254
Cenchrus ciliaris	LSD	1.00	2.00	18.54000*	.000	-1.60000*	.000	-13.30000	.179	-.01460	.080
			3.00	12.90000*	.000	1.78000*	.000	27.80000*	.007	.01840*	.029
			4.00	29.06000*	.000	2.06000*	.000	44.10000*	.000	.01310	.115
		2.00	1.00	-18.54000*	.000	1.60000*	.000	13.30000	.179	.01460	.080
			3.00	-5.64000*	.041	3.38000*	.000	41.10000*	.000	.03300*	.000
			4.00	10.52000*	.000	3.66000*	.000	57.40000*	.000	.02770*	.002
		3.00	1.00	-12.90000*	.000	-1.78000*	.000	-27.80000*	.007	-.01840*	.029
			2.00	5.64000*	.041	-3.38000*	.000	-41.10000*	.000	-.03300*	.000
			4.00	16.16000*	.000	.28000	.277	16.30000	.102	-.00530	.517
		4.00	1.00	-29.06000*	.000	-2.06000*	.000	-44.10000*	.000	-.01310	.115

			2.00	-10.52000*	.000	-3.66000*	.000	-57.40000*	.000	-.02770*	.002
			3.00	-16.16000*	.000	-.28000	.277	-16.30000	.102	.00530	.517
Eriochloa fatmensis	LSD	1.00	2.00	15.10000*	.000	-.60000	.335	-4.50000	.528	-.03100	.157
			3.00	9.46000*	.001	.20000	.747	24.10000*	.002	.02740	.210
			4.00	26.90000*	.000	3.20000*	.000	44.60000*	.000	.08680*	.000
		2.00	1.00	-15.10000*	.000	.60000	.335	4.50000	.528	.03100	.157
			3.00	-5.64000*	.032	.80000	.201	28.60000*	.000	.05840*	.010
			4.00	11.80000*	.000	3.80000*	.000	49.10000*	.000	.11780*	.000
		3.00	1.00	-9.46000*	.001	-.20000	.747	-24.10000*	.002	-.02740	.210
			2.00	5.64000*	.032	-.80000	.201	-28.60000*	.000	-.05840*	.010
			4.00	17.44000*	.000	3.00000*	.000	20.50000*	.006	.05940*	.009
		4.00	1.00	-26.90000*	.000	-3.20000*	.000	-44.60000*	.000	-.08680*	.000
			2.00	-11.80000*	.000	-3.80000*	.000	-49.10000*	.000	-.11780*	.000
			3.00	-17.44000*	.000	-3.00000*	.000	-20.50000*	.006	-.05940*	.009
Dactloctenium aegyptium	LSD	1.00	2.00	9.98000*	.000	-.66000*	.002	-8.20000	.056	-.00260	.757
			3.00	5.98000*	.000	1.30000*	.000	8.30000	.053	.02730*	.002
			4.00	21.30000*	.000	2.18000*	.000	20.20000*	.000	.02280*	.010
		2.00	1.00	-9.98000*	.000	.66000*	.002	8.20000	.056	.00260	.757
			3.00	-4.00000*	.004	1.96000*	.000	16.50000*	.000	.02990*	.001
			4.00	11.32000*	.000	2.84000*	.000	28.40000*	.000	.02540*	.004
		3.00	1.00	-5.98000*	.000	-1.30000*	.000	-8.30000	.053	-.02730*	.002
			2.00	4.00000*	.004	-1.96000*	.000	-16.50000*	.000	-.02990*	.001
			4.00	15.32000*	.000	.88000*	.000	11.90000*	.007	-.00450	.592
		4.00	1.00	-21.30000*	.000	-2.18000*	.000	-20.20000*	.000	-.02280*	.010
			2.00	-11.32000*	.000	-2.84000*	.000	-28.40000*	.000	-.02540*	.004
			3.00	-15.32000*	.000	-.88000*	.000	-11.90000*	.007	.00450	.592
Tragus berteronianus	LSD	1.00	2.00	6.52000*	.000	-.10000	.750	-7.20000	.067	-.00090	.859
			3.00	1.60000*	.017	2.06000*	.000	7.70000	.051	.02430*	.000
			4.00	7.20000*	.000	3.34000*	.000	20.90000*	.000	.02640*	.000
		2.00	1.00	-6.52000*	.000	.10000	.750	7.20000	.067	.00090	.859
			3.00	-4.92000*	.000	2.16000*	.000	14.90000*	.000	.02520*	.000
			4.00	.68000	.295	3.44000*	.000	28.10000*	.000	.02730*	.000
		3.00	1.00	-1.60000*	.017	-2.06000*	.000	-7.70000	.051	-.02430*	.000
			2.00	4.92000*	.000	-2.16000*	.000	-14.90000*	.000	-.02520*	.000
			4.00	5.60000*	.000	1.28000*	.000	13.20000*	.001	.00210	.679
		4.00	1.00	-7.20000*	.000	-3.34000*	.000	-20.90000*	.000	-.02640*	.000
			2.00	-.68000	.295	-3.44000*	.000	-28.10000*	.000	-.02730*	.000
			3.00	-5.60000*	.000	-1.28000*	.000	-13.20000*	.001	-.00210	.679

Appendices B: Questionnaire

Appendix B1: Questionnaires for household

Participant Information sheet and informed consent form

Hello everybody, my name is ____________________. I am working in the research team as a data collector for study being conducted on Assessment of Perception and Indigenous Ecological Knowledge of pastoralists in Rangeland degradation management: in Shinile Woreda, Ethiopian Somali regionby Buli Yohannis under supervision of Professor Sileshi Nemomissa andDr. Tamrat Bekele. I kindly request you to lend me your attention and time to explain about biodiversity conservation and the best management practices as the study participant.

The study title: Local and landscape level ecological processes and patterns in shaping plant diversity of rangelands of East Ethiopia

Sub title: Assessment of Perception and Indigenous Knowledge of pastoralists in Rangeland degradation management: in Shinile Woreda, Ethiopian Somali region

The purpose of the study: The objective of this is to identify the perception of the pastoralists in biodiversity conservation and the best management practices, including knowledge, innovation and practices of indigenous and local pastoral communities.

This study has the potential to point out awareness of pastoral communities on the actual and potential socio-economic benefits of range land and effect of *seero* in conservation and management of plant diversity.

Procedure and duration: You are selected by chance (simple random sampling method) among other household to be one of the study participants. I will interview you in a language of your choice and in a friendly manner based on your cooperation and willingness (Af Somali, Amharic and English). The information that you provideme is very helpful in identifying factors related to the subject matter. There are 23 questions to answer where I will fill the questionnaire by interviewing you and which will take about 25-30 minutes**.** And also there are 16 questions for focal discussion with herders, community leaders and elders.

Risks and Benefits: The risk of being involved in this study is very minimal, it is only taking few minutes from your time. There would not be any direct payment for participating in this study. But the findings of this research reveal important information for the community, policy makers, Non-Governmental organization and others in order to raise the knowledge about rangeland and design appropriate program to alleviate plant diversity degradation.

Confidentiality: The information that you provide me will be kept strictly confidential. There will be no information that will identify you in particular. The findings of this study will be general for the study community and will not reflect any thing particular of individual persons. No reference will be made in oral or written reports that could link participants to the research.

Rights: Participation for this study is fully voluntary. You have full right and free choice to either participate or not in this study and it will never affect your right of getting appropriate community service.

Consent form

Respondent's signature________________ if no, skip to the next participant

Date of interview: ________________ Time started: _______ Time finished: _________

Interviewer Name__________________________Signature___________Date____________

Supervisor's name ________________ signature ________

Results of interview questionnaire

1. Completed
2. Partially completed

Name of the institution _________________________________

1. Questionnaires for household on rangeland vegetation condition

1.1. DO YOU EVALUATE RANGELAND CONDITION?

a) Yes

b) No

1.2. WHAT DO YOU THINK ON CONDITION OF RANGELAND?

a) Good

b) Poor

1.3. WHAT ABOUT TRENDS OF RANGELAND?

a) Downward trend

b) Upward trend

c) The same as before

1.4. WHAT IS YOUR OPINION ON RANGELAND GRASS COVER?

a) Increasing

b) Decreasing

c) The same as before

1.5. DO YOU OBSERVE DECREASE OF RANGELAND VEGETATION?

a) Yes

b) No

1.6. WHAT IS YOUR OPINION FOR the MAIN CAUSE?

a) Overgrazing

b) Drought

c) Uncontrolled livestock movement

d) Increase Population Number

e) I don’t know

1.7. WHAT DO YOU THINK OF THE HIGHEST CONSEQUENCE OF RANGELAND VEGETATION LOSS?

a) Shortage of fodder

b) Death of herds

c) Increase migration

d) Food insecurity

2. Questionnaires for household on Soil condition

2.1.DO YOU OBSERVE AN INCREASE IN SOIL DEGRADATION?

a) Yes
b) No

2.2.WHAT IS YOUR OPINION FOR LEADING CAUSE?

a) Drought
b) Overgrazing
c) Uncontrolled livestock movement
d) Lack of Protection
e) I do not know

2.3.WHAT DO YOU THINK OF MAIN CONSEQUENCE OF SOIL DEGRADATION?

a) Shortage of fodder
b) Shortage of land productivities
c) Increase herd death
d) Increase migration
e) Change to more aridity

2.4.HAVE YOU PRACTICE SOIL CONSERVATION ACTIVITIES?

a) Yes
b) No

2.5.WHAT ARE THE MAJOR ACTIVITIES YOU HAVE PRACTICED?

a) Terracing
b) Tree plantation
c) Check dam
d) Waterway
e) Cutoff drain

2.6.WHAT ARE CHANGE YOU GET FROM YOUR ACTIVITIES?

a) Increase Soil productivity
b) Increase land cover
c) Both

3. Questionnaires for household on status of rangeland enclosure

3.1.DO YOU HAVE ENCLOSURE?

a) Yes

b) No

3.2.WHAT KIND OF ENCLOSURE YOU HAVE?

a) Private

b) Communal

c) Both

3.3.FOR HOW LONG YOU USE ENCLOSURE?

a) Less than 5 year

b) 5 to 10 years

c) 10 to 15 years

d) 15 to 20 years

e) More than 20 years

3.4.DO YOU USE MANAGEMENT TO EMPROVE ENCLOSURE?

a) Yes

b) No

3.5.TYPE OF MANAGEMENT USED?

a) Fencing every year

b) Cleaning Bush and weed

c) Both

3.6.WHAT KIND OFANIMAL YOU FEED IN ENCLOSURE PRIMARLY?

a) Lactating Animal

b) Pregnant animal

c) Sick animal

d) Young animal

e) All herds

3.7.IN WHICH SEASON ENCLOSURE USED COMMONLY?

a) Wet season

b) Dry season
c) Both

3.8. WHAT DO YOU THINK ABOUT OTHER ROLE OF ENCLOSURE?

a) Drought mitigation
b) Rehabilitation
c) Both

3.9. ARE YOU GOING TO CONTINUE LAND ENCLOSURE?

a) Yes
b) No

3.10. WHAT ABOUT THE PRODUCTIVITY OF RANGELAND WITH ENCLOSURE?

a) More productive
b) Productive
c) Less productive

Appendix B2: Focal discussion for expert (herders), leaders and elders to identify whether the following indicators are identifies rangeland degradation based on indigenous ecological knowledge of pastoralist. We used check mark (√) to the indicators if all stakeholder were agree and (-) if they disagree

Attributes	Indicators	Check mark
Vegetation	Reduction of palatable grass	
	Invasion of exotic plants/weeds	
	Increase in annual plants	
	Bush encroachment	
	Decrease of vegetation yield	
	Decline of plant biodiversity	
Soil	Increase dust in air	
	Increase soil erosion by water	
	Increase soil erosion by wind	
	Decrease Soil fertility	
Other	Food insecurity, food aid and poverty	
	Reduced livestock number per HH	
	Shift to crop land	
	Recurrent drought	
	Poor livestock output	

Appendix C: Sampling Formats and Notes

Appendix C1: Vegetation layer sampling format

Date________________ Name of the site__________________________

District: - ___________________

Location: -

Longitude _______________ Latitude________________Altitude____________

Quadrate No._______________

S.N	Vernacular name	Scientific name	Spp. Count	Bot. Group	Plot Location				Remark
					IEUA	IEWA	OEUA	OEWA	
1									
2									
3									
4									
5									
6									
8									

Appendix C2: Plant specimen notes

Specimen No.____________

Date________________ District_______________ Name of the site________________________

Vernacular name______________ scientific name_______________________________

Botanical group: - Grass……….. Forb/weed………… Shrub………… Tree…………

Plot Location: - IEUA ……….. IEWA………….. OEUA………... OEWA………….

Location: - Longitude _________________ Latitude___________________ Altitude____________

Quadrate No._______________

Name of Collector__________________________ Signature__________________

Appendix C3: Soil sampling notes for chemical analysis

Paper bag No.___________

Date_______________ District______________ Name of the site______________________

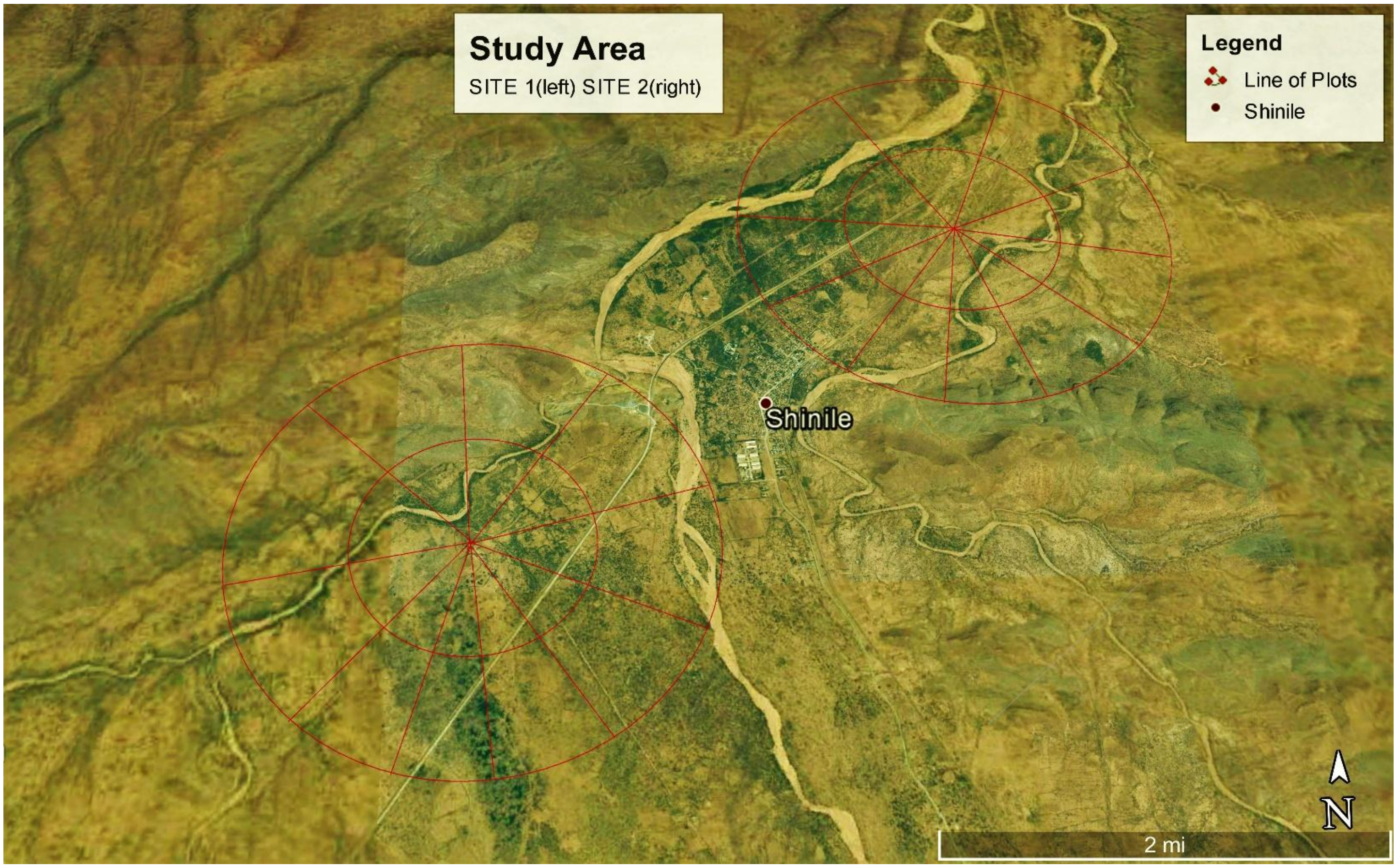
Plot Location: - IEUA ……….. IEWA………….. OEUA………... OEWA………….

Location: - Longitude ________________ Latitude__________________ Altitude___________

Quadrate No.______________

Name of Collector________________________ Signature_________________

Appendices D: Pictures



Appendix D1: Map of major grazing areas and sampling sites in Shinile Woreda

Appendix D2: Picture showing how to construct enclosure

Appendix D3: Picture showing inside of the enclosure and acacia canopy improves herbaceous species

Appendix D4: Picture showing overgrazed outside of enclosure

Appendix D5: Picture showing herbaceous collection at inside enclosure under canopy using quadrat method

Appendix D6: Pictures showing herbaceous species collection from field.

Appendix D7: Picture showing cattle others on communal grazing during dry season.