ASSESSING THE ACCESSIBILITY, CONSERVATION AND PRODUCTION OF FODDER FOR LIVESTOCK FOR THE AGRO-PASTORAL SOCIETIES IN MAGU DISTRICT, TANZANIA

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A Dissertation Submitted in Partial Fulfilment of the Requirement for the Degree of Master of Science in Biodiversity and Ecosystem Management of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

The access to adequate and high-quality livestock fodder has become a great challenge which in turn threatens the sustainability of the agro pastoral societies in Magu district. This study was done to assess the accessibility, conservation and production for the agro-pastoral societies in Magu district, Tanzania**.** Systematic random sampling technique was used to select the sample plots allocation and the households for interview in the study area. The findings revealed that there are no significant differences in diversity and relative species abundance between the highland and lowland agro-ecological zones ($p = 0.009$ and $z = 45.5$). However, the results show significant differences in the diversity of fodder species between the highland and lowland zones. Household survey was done to assess the accessibility, conservation and production of livestock fodder. The results reveal that, seasonal variation (dry and wet) shaped the accessibility of fodder within the agro-pastoral households. Households land size, number of livestock, and physical capital indicated a positive influence ($p = 0.009$, $p = 0.083$, $p = 0.002$ respectively) on the accessibility of fodder in the wet seasons while, households' land size, physical capital and the number of livestock ($p = 0.000$; $p = 0.027$; $p = 0.075$ respectively) indicated the negative influence during the dry season. Households' head level of education and income ($p = 0.035$; $p = 0.087$) show a greater influence on the conservation of rangelands and fodder sources. Results also show that the need for livestock feed and the need to protect the environment both motivate agro-pastoralists to invest in fodder production however, poor assets households were more interested in livestock feed than their counterparts. Therefore, this study suggests the need to improve the community livelihood by enhancing households' socioeconomic development through extension services regarding fodder and livestock production.

DECLARATION

I, Glory Khanje Rustis, declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is entirely my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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CERTIFICATION

The undersigned certify that they have read the dissertation entitled **"Assessing the accessibility, conservation and production of livestock fodder for the agro-pastoral societies in Magu district, Tanzania"** and recommend as an achievement of the requirement for the degree Master of Science in Biodiversity and Ecosystem Management of the Nelson Mandela African Institution of Science and Technology.

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DEDICATION

I devote this dissertation to the LORD JESUS, my redeemer, my provider and my strength throughout this study.

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LIST OF ABBREVIATIONS AND SYMBOLS

CCM	Chama cha Mapinduzi
CP	Crude Protein
DM	Dry matter
FAO	Food and Agriculture Organisation
FGD	Focus Group Discussion
GDP	Gross Domestic Product
KIIs	Key Informants Interviews
LVB	Lake Victoria Basin
ME	Metalizable energy
MJ	Mega joules
NTFPs	Non-timber Forest Product
R^2	Pseudo R-square
SD	Standard Deviation
SE	Standard Error
SSA	Sub Sahara Africa
URT	United Republic of Tanzania
VIF	Variance Inflation Factor
W	Wilcoxon Rank sum test
Z	Mann Withney U Test

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Livestock contributes about one third of total global agricultural based Gross Domestic Product (GDP) (Crump *et al.,* 2018). Livestock keeping is also a vital source of food to both urban and rural communities (Crump *et al.,* 2018). According to Komba and Mahonge (2018), historically, pastoralism is among the most common agricultural activities that are widely conducted by most African communities. Together, crop cultivation and livestock keeping, commonly referred as agro-pastoralism is a vital source of food which sustains the livelihoods for rural communities in developing countries (FAO, 2018). Agro pastoral practices are also becoming more popular among smallholder pastoralists who are shifting from pure pastoralism livelihoods to agro-pastoralism due to challenges that lead to lower livestock productivity as decline of fodder due to land fragmentation caused by the gradual increase in human population and climatic changes (Schmidt & Pearson, 2016).

Livestock production challenges are expected to increase with the increasing impacts of global climate change (Chakeredza *et al.,* 2007; FAO, 2013). Yet, in sub-Sahara African (SSA) countries, the livelihoods of more than 200 million people depend on crop cultivation and free range livestock keeping system (FAO, 2018; Otsyina & Magayane, 2004). In East Africa, Lake Victoria Basin (LVB), is an important area for livestock production, where about 60% of LVB is rangeland (Ernest *et al.,* 2017). The area is also a catchment for Lake Vitoria, which is the key source of water for the river Nile. The LVB contributes 10-20% of the GDP in the East African economies (URT, 1998). Over 36% of the livestock in Tanzania, are found in the Lake Victoria zone (Ernest *et al.,* 2017), and agro-pastoralism is predominant among smallholder farmers in this area (Biradar *et al.,* 2003). However, agro-pastoralism in Tanzania is characterized by low production due to total reliance on rain-fed agriculture, declining soil fertility, decreasing access to grazing land, and lack of fodder (Singh *et al.,* 2003). In Magu district for example, about 90% of the population is engaged in crop cultivation and livestock keeping (URT, 1998). Shortage of livestock fodder in LVB is therefore a huge threat to the agro-pastoral livelihoods in Magu district communities (Ernest *et al.,* 2017). Production and conservation of improved fodder, therefore is a crucial step toward sustaining the livelihoods of rural communities who depend on livestock production.

Fodder comprise any agricultural foodstuff used specifically to feed domesticated livestock (Gachuiri, 2013). Thus, production of high protein fodder such as *Leucaena leucocephala, Calliandra, Mulberry, Sesbania, Desmodium, Tithonia,* and other forage plant materials can improve livestock productivity (Graefe *et al.,* 2008; FAO, 2018). However, lack of arable land for fodder cultivation, drought stress, lack of appropriate knowledge to grow fodder, shortage of fodder seeds, and destruction of natural vegetation due to rapid human and livestock population growth are common challenges to fodder production (Kariuki, 2018; Maleko, 2020; Omollo *et al.,* 2018) and conservation in LVB (Ernest *et al.,* 2017). Conservation of rangelands is fundamental in sustaining livestock fodder in the dry and wet seasons (Selemani *et al.,* 2013). Conservation of fodder sources reduce the land pressure caused by overgrazing resulting to increase of livestock production, and improves agro-pastoral communities livelihood (Gachuiri, 2013). For instance; the semi-arid parts of north-western Tanzania, the agro-pastoral community have a tradition of conserving livestock feed during the rainy season to be used in the dry season when the feed is limited (Kamwenda, 2002). Some of the agro-pastoral communities have adopted fodder production technology (small scale pasture establishment) and grazing management strategy to enable easy availability and accessibility of high-quality fodder by avoiding invasive and unpalatable species (Selemani *et al.,* 2013). On the other hand, fodder production in some regions of Tanzania has been viewed among the appropriate strategies for improving availability of livestock feed (Chakeredza *et al.,* 2007).

Although there are some of practices and technologies for improving fodder availability such as over-sowing of natural pasture with superior fodder species, the establishment of improved fodder, promotion and planting of fodder trees and legumes, forage conservation and effective use of crop residues (Omollo *et al.,* 2018; Wairore *et al.,* 2015). Availability and accessibility of adequate quality fodder in the agro-pastoral communities remains challenge (Omollo *et al.,* 2018; Rai, 2018; Sala *et al.,* 2020). Factors affecting community uptake of available fodder production and conservation practices and technologies are not studied. Napier grass (*Pennisetum purpureum*), Guatemala (*Tripsacum andersonii* J. R. Gray), *Cenchrus ciliaris* and *Chloris gayana* for example are among the forage species with high yielding that are highly promoted to improve feed availability and accessibility in tropics (Hassa, 2018; Maleko, 2020) but community acceptance remains low (LeHouerou, 2000; Sanderson *et al.,* 2007). Therefore, understanding the factors influencing rural communities

participation in producing and conserving fodder is crucial to contribute to the sustainable availability of fodder (Omollo *et al.,* 2018).

This dissertation therefore exploited Magu district as a case study to addresses challenges limiting fodder accessibility. Magu district is dominated by pastoral communities but information concerning the accessibility of livestock fodder, conservation of fodder sources and production of fodder for the sustainability of agro-pastoral societies remains elusive. The study assesses the different socio-economic factors which may influence the availability, accessibility, conservation of fodder sources, and the interests of the community to invest in fodder production to inform management strategies for the protection of the LVB and improve the livelihoods pastoral communities.

1.2 Statement of the Problem

The livestock sector in Tanzania is facing various problems such as shortage of grazing lands, prolonged droughts, and lack of quality fodder (Singh *et al.,* 2003). Fodder scarcity, especially during the dry season, is the main reason for decreasing livestock productivity which is essential source of income in the agro-pastoral communities (Maleko *et al.,* 2018). The shortage of fodder is exacerbated by climatic changes and variability, land tenure system, population growth, rangeland degradation and fragmentation, and extension of crop fields in rangelands (Paterson *et al.,* 1998; Tolera & Abebe, 2007). Yet, despite the importance of livestock production in sustaining livelihoods and food security, the available information in academic and grey literature on fodder focus on quality (fodder nutrition) and quantity (fodder production) (Chakeredza *et al.,* 2007; Mutimura & Everson, 2011; Lugusa, 2015; Moges & Taye 2017; Maleko *et al.,* 2018). Few studies have investigated on the socioeconomic determinants of pastoral communities for adoption of forage production technology and livestock production, in Southern Ethiopia and Africa at large (Omollo *et al.,* 2018; Yeneayehu *et al.,* 2019; Tolera & Abebe, 2007). However, there are no published studies on socioeconomic determinants of fodder accessibility and availability in Magu district of Tanzania. This study, therefore fills this information gap by assessing factors influencing the accessibility, conservation and production of fodder for the livestock for the agro-pastoral livelihoods societies in Magu district, Tanzania.

1.3 Rationale of the Study

Fodder availability and accessibility of livestock feed is important for enhancing agro-pastoral households' income and food security. This study contributes to the body of knowledge on fodder availability and accessibility. The information can be used to improve agro-pastoral livelihoods by informing state and non-state actors, policymakers, and experts on the factors that influence the households to invest and participate in fodder production and conservation.

1.4 Objectives of the Study

1.4.1 General Objective

To assess the accessibility, conservation and production of livestock fodder for the agro-pastoral livelihoods societies in Magu district, Tanzania.

1.4.2 Specific Objectives

The study aimed to achieve the following specific objectives:

(i) To assess fodder species, diversity and above-ground biomass of forage species in Magu district, Tanzania.

(ii) To determine factors influencing the households' fodder accessibility and conservation of fodder sources in Magu district, Tanzania.

(iii) To determine the factors influencing households' interest to invest in fodder production in Magu district, Tanzania.

1.5 Research Questions

The study intended to answer the following questions:

(i) What are the fodder types used, their diversity and production quantity in the study area?

(ii) Which factors influence households' access to fodder and participation in conservation of fodder sources?

(iii) Which factors influence farmers' investments in fodder production?

1.6 Significance of the Study

This study generates information that contributes to the managements of fodder for the government and other livestock actors to improve the livelihood of agro-pastoralists (Fig. 1). In addition, the information can facilitate state and non-state actors to promote sustainable ways for livestock production in LVB and beyond.

1.7 Delineation of the Study

This study focuses on providing information to improve fodder availability and accessibility on different locations of Magu district including the reserved highlands (Ngitiri areas), open areas, and crop lands. However, the LVB is very large area comprising people with diverse culture, traditions, socioeconomic and legal arrangements from four countries. The differences in socioeconomic, legal and traditional arrangements therefore may limit the extrapolation and application of the results to other parts of great LVB.

CHAPTER TWO

LITERATURE REVIEW

2.1 Livestock Keeping and Agriculture Activities

Livestock keeping plays a key role in many agro-pastoral societies as the main source of food and incomes (deGlanville *et al.,* 2020). In Tanzania, where the majority of its population depends on agricultural activities (Meertens & Consult, 2016; URT, 2017). Agricultural activities generate 70% of the total income for the rural households (Ministry of Livestock and Fisheries, 2017) and livestock. It is also the backbone for social, cultural, and economic security for communities in semi-arid environments in Tanzania (FAO, 2011). However, the livelihoods of agro-pastoral societies are under huge pressure due to the effect of climate change and variability, which reduce livestock productivity (Ernest *et al.,* 2017; Nkya *et al.,* 2018; Kariuki, 2018). Climate change has resulted to severe drought in some parts of East Africa including in Northern Tanzania where in 2009 about 90% of livestock died due to drought related challenges (Id *et al.,* 2020).

Tanzania is one of the countries with the largest livestock population in Africa (FAO, 2013). According to the 2012–13 National Panel survey, 4.6 million households own livestock with ownership patterns dominated by chickens (86%), goats (48%), cattle (35%), pigs (9%) and other livestock (FAO, 2013; Ministry of Livestock and Fisheries, 2017). About 50% of the households in Tanzania are keeping livestock for economic purposes. Selling of livestock products contributes the annual income of 15% for the livestock-keeping households (deGlanville *et al.,* 2020; Id *et al.,* 2020). However, livestock keepers are faced with many challenges including changing land tenure systems from communal to private (LeHouerou, 2000; Wairore *et al.,* 2015), and conversion of communal lands to protected areas which result to reduced access to grazing land (Gessesse *et al.,* 2016; Wairore *et al.,* 2015). Strengthening land tenure system can increased livestock movement and allow the agro-pastoralist to utilize pasture land on common land over a potentially wide geographic area (Chisanga *et al.,* 2019; Mengistu *et al.,* 2021), hence improving productivity and community wellbeing (Roy & Singh, 2008).

In Magu district, the challenges of limited access to grazing lands, together with deterioration of fodder availability due to climatic change, human population growth, and urbanisation has impelled pastoralists to adopt crop production, moving away from pure pastoralism to agro-

pastoralism (Schmidt & Pearson, 2016). The rangeland area in Magu district has deteriorated from 47 337 ha in 1980 to 7423 ha in 2010. The decrease is mainly due to climate change caused by seasonal rainfall patterns; land fragmentation attributed to land use change driven by land demand for agriculture; and urbanization (Kariuki, 2018). Currently, the leading economic activities in Magu district is crop production where cotton (*Gossypium hirsutum*), paddy (*Oryza sativa*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), sweet potatoes (*Ipomoea batatas*), cassava (*Manihot esculenta*), grain legumes; and horticultural crops such as tomatoes (*Solanum lycopersicum*), onions (*Allium cepa*) and fruits are major crops (Ernest *et al.,* 2017). However, the district is estimated to have total of 300 000 heads of cattle (60 are dairy and 299 940 are local breeds), 120 000 goats, 80 000 sheep, 500 donkeys, and 55 pigs. (Otsyina & Magayane, 2004).

2.2 Fodder Availability and Accessibility

Availability of fodder in most of the tropical areas is seasonal with limited availability during the dry season compared to rainy season (Maleko *et al.,* 2018). Fodder availability is influenced by the climatic condition, farming system, and grazing land (Biradar *et al.,* 2003). According to Ernest *et al.* (2017); Development and Summit (2014), Gomes (2006) and Kariuki (2018) changes in the availability of water and pasture for livestock can be influenced by urbanization, population growth, informal settlements, and expansion of crop lands. Livestock are underfed on communities where the forage production have not yet been established or rather conserved as hay or silage but obtained from open areas such as fallow lands, play grounds, road sides, crop fields and river banks (Hassen *et al.,* 2010; Van Noordwijk *et al.,* 1996). Most farmers depend on the available natural forages and crop residues to feed livestock in the dry season (Egeru *et al.,* 2015; Peters *et al.,* 2001; Simbaya, 2009). Crop residues are obtained from cereal crops (Maleko *et al.,* 2018), including maize stover, legume haulms, and rice straw (Mtengeti *et al.,* 2008) which has low crude protein (CP) ranging from 260 g/Kg DM and ME of 7.5 MJ/Kg DM (Weller & Jones, 2002).

Availability of adequate and quality fodder, especially in the dry season, is among the major limitations for livestock production in Tanzania (Mtengeti *et al.,* 2008). However there are some regions such as Shinyanga, Tabora, and Mwanza which have started to adopt fodder production to solve the problem of fodder availability (Selemani *et al.,* 2013). Yet, limited access to improved fodder seeds and erratic rains restricts the adoption of fodder production technologies (Charambira *et al.,* 2021; Mengistu *et al.,* 2021). Besides, fodder can be

available but not accessible to livestock keepers due land tenure arrangements and other socioecomic and geographical factors (Rai, 2018) such as topography of the area, the laws and bylaws of that particular area (Kariuki, 2018).

2.3 Fodder Production

Fodder production is regarded as one of the strategies for increasing fodder availability to enhance livestock production among communities globally (Yeneayehu *et al.,* 2019). Community participation in the production of fodder crops is a vital component in the development of livestock production (Omollo *et al.,* 2018; Sala *et al.,* 2020). Studies on determinants of community participation in forage production, and adoption of forage production technologies among smallholder farmers in Africa show that community adoption of forage production is hindered by poor dissemination of relevant information, lack of financial assistance such as credits an subsidies, and limited extension services (Hassa, 2018; Peters & Lascano, 2003; Omollo *et al.*, 2018; Yeneayehu *et al.,* 2019). The perception of livestock keepers to invest in fodder production technologies is highly influenced by the socio-economic, institutional, attitudinal, and biophysical factors (Moges & Taye, 2017). Thus to ensure the availability of adequate livestock feed effort must be directed towards determining factors affecting community adaptation and uptake of fodder production technologies (Peters *et al.*, 2001; Weller & Jones, 2002; Biradar *et al.,* 2003; Charambira *et al.*, 2021; Mutimura & Everson, 2011).

2.4 Fodder Sources and Resources

Agro-pastoral societies use different feed resources such as grasses, legumes, field crops planted for hay, silage, feed grain, green and succulent feed, and agro-industrial by products (Mutimura & Everson, 2011; Van-Zanten, 2016). In contrast, the common feed resources in many African agro-pastoral societies are natural pastures such as grasses, forbs, browses such as shrubs, tree leaves and pods (Simbaya, 2009; Tolera & Abebe, 2007). Pastoralist usually obtain these natural pastures by grazing or cut and carry method (Van-Zanten, 2016), on different sources such as open area, road sides, crop fields, abandoned fields, and forest areas (Maleko *et al.,* 2018). Scarcity and inadequate feed resources are the main setbacks on improving the livelihood of most agro-pastoral societies (Place *et al.,* 2009). Rapid human population growth is greatly contributing to the shortage of grazing land where rangelands is mostly converted to other land use (Mutimura & Everson, 2011). However, interventions to

utilize locally available potential feeds, improve access to forage and fodder production is seen as a way forward to enhance livestock production (Development & Summit, 2014; Sala *et al.,* 2020). Yet, these strategies can be successful if backed-up with consistent and persistent monitoring programs that hinges on institutional framework to ensure sustainability.

2.4.1 Grasses and Herbs

Grasses are grazed plants belonging to the family *Gramineae or Poaceae.* The grazed plants from Gramineae family are annual fast growing grasses characterized by high energy and low crude protein (Ajoy *et al.,* 2006). In Africa more than 90% of the ruminant livestock are reared in rangelands where grasses are main forage resource (Kariuki, 2018). During the dry season, rangelands become almost dry leaving the community who are dependent on the natural forage at risk (Hassen *et al.,* 2010; Tolera & Abebe, 2007). According to Maleko (2020), Bacigale *et al.* (2018) and Simbaya, (2009), grass species with high yield that are suitable for improving livestock feed availability in tropics include Napier (*Pennisetum purpureum*), Guatemala (*Tripsacum andersonii*), buffel grass (*Cenchrus ciliaris*) and Rhodes grass (*Chloris gayana*).

Other grazed plants are short herbs including *Arachis pintoii*, *Sorghum almum* (Columbus grass), *Digitaria smutsii* and *Brachiaria ruziziensis* that are consumed with leaves and stems (Ajoy *et al.,* 2006; Hassen *et al.,* 2010). Depending on the nature and shape of their flowers, herbaceous plants including legumes are belonging to three different families (*Mimosoideae, Caesalpinoideae* and *Papilionaceae*) (Hassen *et al.,* 2010). The herbs are characterized by broad leaves with net venation pattern (Hassa, 2018). In Magu district shortage of grasses and herbs has been a great challenge that led to the decline of livestock production (Ernest *et al.,* 2017; Nkya *et al.,* 2018). These results to conflicts among land users and some of the agro-pastoralists are shifting to other regions searching for pastures (Kizima *et al.,* 2014).

2.4.2 Hay

Hay is a fodder crop which is harvested and stored in a dried form (about 15% water content) to be used at times where the forage is limited especially during dry seasons (LeHouerou, 2000). Fodder crop for hay production should be harvested at the flowering stage when there are enough nutrient contents (FAO, 2020). The commonly used crops for hay-making are alfalfa (*Lucerne*), sweet clovers, vetches, cereals, and mixed crops (Bacigale *et al.,* 2018), but

the most suitable grass species for hay making are leaves with thin stem such as Rhodes grass (*Chloris gayana*), buffel grass (*Cenchrus ciliaris*) and *Cynodon spp*, this is because they are simple to cure (Maleko, 2020; Weissbach, 2019).

The quality of hay depends on the stage of harvesting the forage and the season (Hassa, 2018). Good-quality hay improves the health of livestock and increase productivity when supplemented with other quality animal feed ingredients (Weissbach, 2019). However, hay-making is a simple practice and a widespread method used to conserve and ensure the availability of fodder especially on dry seasons, with or without some form of mechanization (FAO, 2020; Sabry *et al.,* 2019). Therefore, farmers need to be well informed on how they can practice this method to ensure the quality feed, with sufficient nutrients are available during dry and wet seasons.

2.4.3 Silage

Silage is preserved forage that has undergone complete anaerobic fermentation for a period of time. Production of silage needs a fresh forage material to be harvested at appropriate stage of pasture growth (Ford, 2003). The fresh forage material can be wilt or used directly with its moisture content (Weissbach, 2019). Silage is normally produced in a farming system where it interacts with many other farm components (Ford, 2003). For example, silage from corn (*Zea mays L.*), alfalfa (*Medicago sativa L.*), perennial forage grass, and small grain crops can be cultivated on the same farm along with grain crops where they are used to feed one or more types of animals (Maleko *et al.,* 2018). Silage production can be used to promote and enhance the availability of quality and acceptable livestock feed to solve the challenges of fodder among the agro-pastoral communities (Tripathi *et al.,* 1995; Weissbach, 2019). However, the production of silage is more expensive because it requires knowledge and money to make it perfect (Goto *et al.,* 2013). Thus, makes the fodder grasses and herbs to be more crucial within the communities as most of the agro-pastoralist depend much on the natural pastures to feed their livestock (Ajoy *et al.,* 2006; Peters *et al.,* 2001).

2.5 Rangelands and Forage Conservation

Rangelands occupy 35% of the African land surface including grasslands, shrub lands and savannahs used largely for livestock production and wildlife conservation (Farley *et al.,* 2017; Kariuki *et al.,* 2018). Rangelands are often characterized by low production caused by soil degradation (Kariuki, 2018). In Africa, rangeland degradation is largely caused by rapid

population growth, increase of urbanization, and uncontrolled livestock grazing (Barry & Huntsinger, 2021; Selemani *et al.,* 2013). Effective utilization and conservation of fodder sources are of great importance because it ensures the sustainability of livestock feed in relation to the pastoral challenges encountered on agro pastoral societies (Barry & Huntsinger, 2021; Farley *et al.,* 2017). In Tanzania, particularly in semi-arid parts (north-western Tanzania), agro-pastoral communities have long history of conserving parts of their lands (Ngitiri) to be used during dry season when the feed is scarce (Kamwenda, 2002). The reserved areas can be community or privately owned (Farley *et al.,* 2017).

However, forage conservation technologies are a widely available in the developed countries but still growing in developing countries including Tanzania (Goto *et al.,* 2013; Tripathi *et al.,* 1995). Forage can be kept as an excess feed resource for future use in form of hay, silage, leaf meal or straws (Weissbach, 2019; Yeneayehu *et al.,* 2019). Moreover, the perception of farmers to invest in forage conservation technologies is highly determined by the socio-economic characteristics such as education level, land ownership, plot size, slope type, and extension contacts (Moges & Taye, 2017). Limited knowledge, low level of mechanization, transport costs, and limited storage facilities limits the adoption and implementation of fodder conservation technologies in the developing countries (Goto *et al.,* 2013). Furthermore, households gender, level of education, social participation as well as access and implementation of extension services, play key role in adaptation of fodder conservation technologies, and hence enhancement of fodder quality and quantity (Omollo *et al.,* 2018; Yeneayehu *et al.,* 2019).

2.6 Conceptual Framework

This study assumed that, a healthy rangeland, fodder availability, accessibility, and community willingness to conserve fodder sources would improve livestock production and agropastoral livelihood and socioeconomic factors (age, gender, education) and household assets (land holdings, number of livestock, households' income, households' size, physical capital) would facilitate the accessibility and conservation of rangelands by the household (Fig. 1).

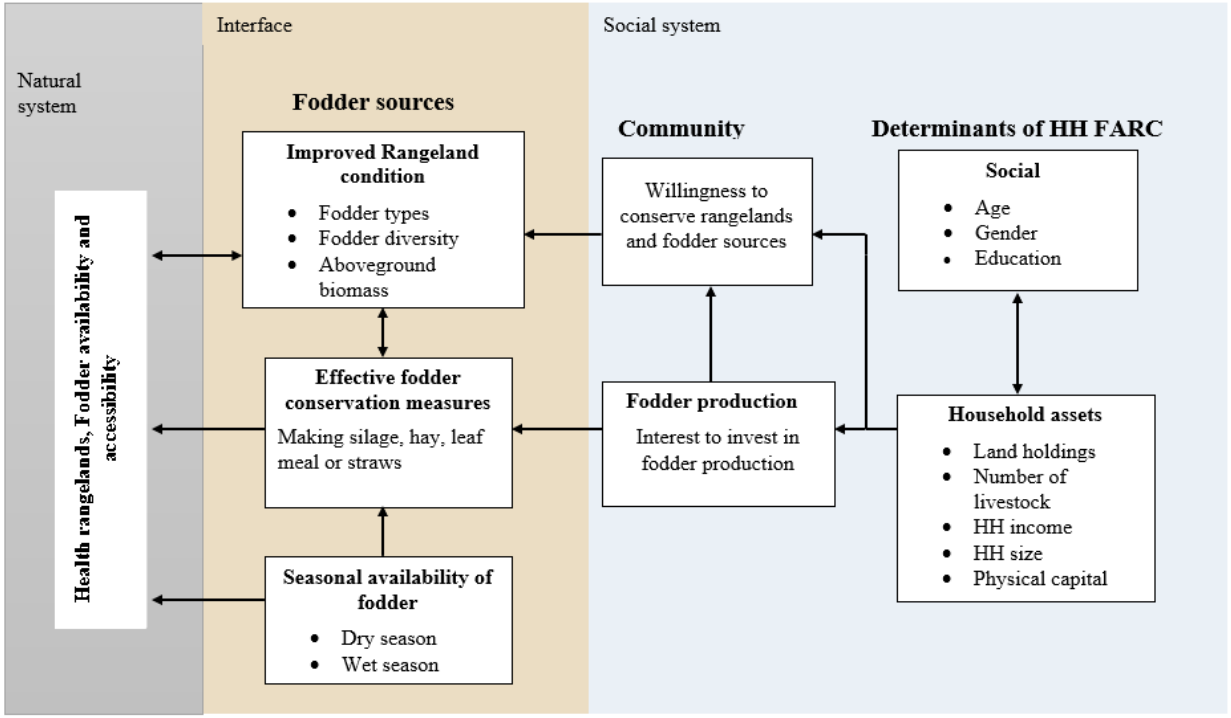

Figure 1: Conceptual Framework

Key: HH - Household; FARC - Fodder Accessibility and Rangeland Conservation

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area Description

This study was conducted in Magu district (Fig. 2), located between latitudes 2^0 10' and 2^0 50' South and between longitudes 33^0 and 34^0 East. Magu district has a tropical temperature ranging between 25℃ and 30℃. The rainfall pattern is bimodal in nature with an average of 800 mm per annum, and ranges between 700 mm and 1000 mm in October to December and March to May. The temperature and rainfall are strongly influenced by proximity to Lake Victoria and the Equator (Ernest *et al.,* 2017). The district has a total area of 4800 km^2 of which 1725 km^2 is covered by Lake Victoria. Fifty percent (2363 km^2) of the land area is considered as arable, 30% (1440 km^2) is pastoral land, and 3.4% (163.2 km^2) is natural and planted forests (Otsyina & Magayane, 2004). Magu was selected among other districts of Mwanza region because it is among the Tanzanian districts dominated by the pastoral and agro-pastoral communities (Ernest *et al.,* 2017). Within Magu district, three wards (Kahangara, Nyigogo, and Lubugu) were randomly selected as a sample population for this study.

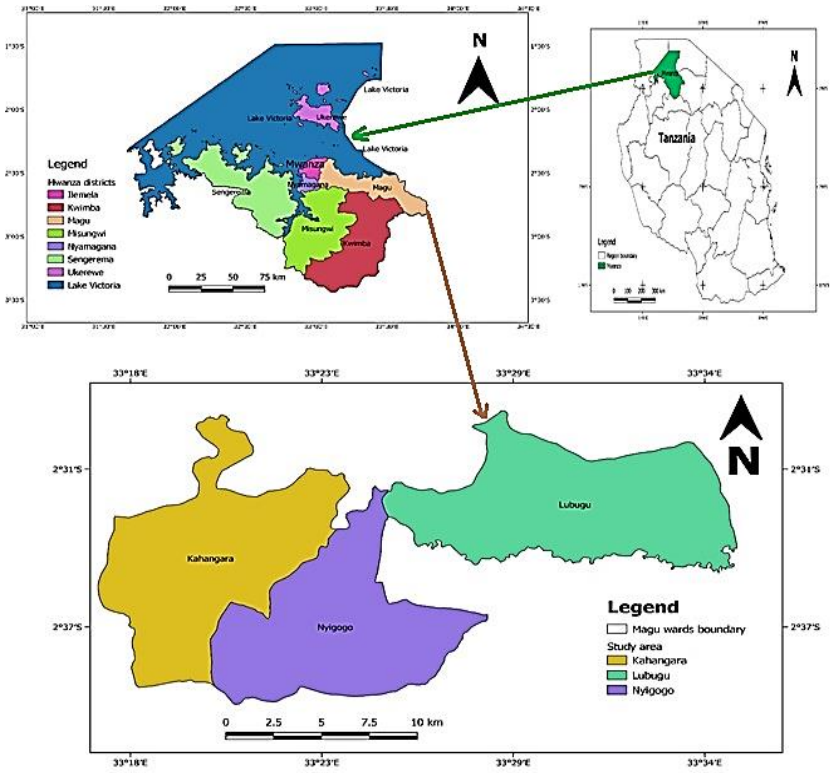

Figure 2: A map of Magu district showing location of the study area

3.2 Reconnaissance Survey

Reconnaissance survey was conducted in February 2021that aimed to identify the sample size in terms of number of households to be surveyed and sample plots for data collection. During the reconnaissance survey, apart from getting acquainted with the environments of the study sites, the time was also used to introduce the study to the local communities including the agro-pastoralists and the management. The introduction was conducted through consultative meetings with local governing bodies and individuals including district councils, ward councils, village councils and the agro-pastoralists.

3.3 Fodder Types, Diversity and Aboveground Biomass of Forage Species

3.3.1 Sampling Design and Data Collection

A systematic random sampling design was employed by using a topographic map of the study area which was marked with equal grid squares of 10 km x 10 km size. Also, a multistage sampling (grids and cluster plots) was conducted, where 14 km transect was lied on each selected grid, and two cluster plots of 10 m^2 were established in 7 km distance away from each other along the transect as shown in Fig. 3. Each cluster plot contained 5 subplots of 1 m^2 in size each, where the samples were collected. The number of plots was calculated by using the modified formula proposed by FAO (1999) as in Equation 1.

$$\text{Number of plots} = \frac{\text{Area of the cluster (acres)} \times \text{Sampling intensity}}{\text{Area of the plot (acres)}} \quad (1)$$

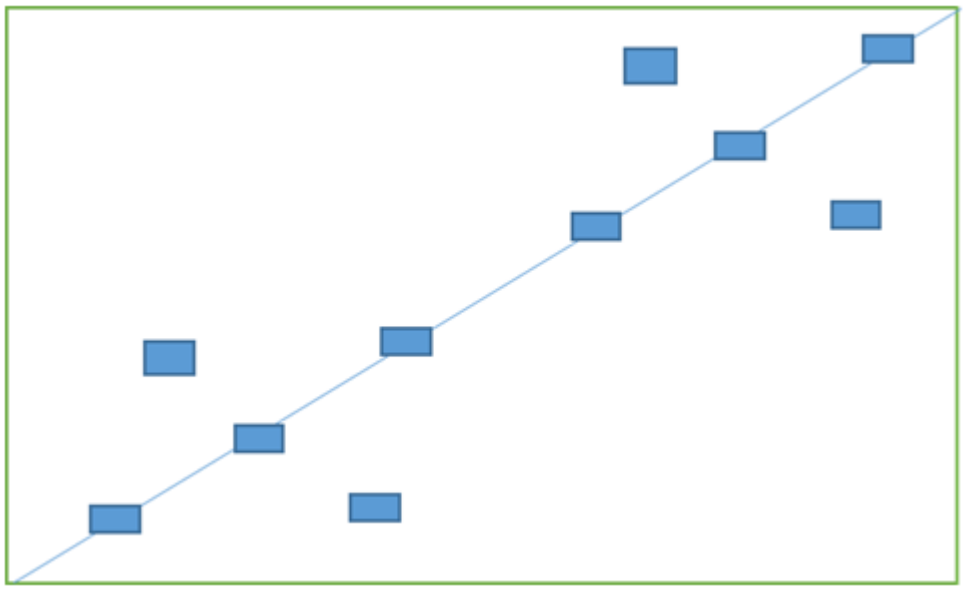

Figure 3: Transect layout indicating data collection points

According to IUCN land use categories, the land use in the study area falls under the unprotected areas which is the open land use category. The open land use includes the croplands, pasture lands, and settlements. Initially, a reconnaissance survey was done in the study area indicated that, there are no specific areas that were planned purposely for grazing. By considering the land topography, the grazing areas were categorized into two sites (highland and lowland) based on zones that communities use to obtain the fodder. Lowland is mainly used for grazing while highlands are used for cultivation and conservation pasture that is mainly utilized during the dry season. The highlands were sub-hilly land that are locally known as Ngitiri by the agro-pastoral community in the study area. The areas were traditionally set aside for livestock pasture to be used especially during the dry seasons. Not only for livestock pasture but the community are using the grasses as roofing materials. The lowland is open flat grazing areas, including roadsides grazing areas, electrical line grazing areas, and cropland. To get the effective fodder sampling area, the grazing areas that were highly accessible to fodder were considered; thus, are highland (Ngitiri) and lowland (electrical line grazing area).

To map the fodder sources, the coordinates were taken from the place where the pastoralist usually obtain the fodder for livestock (highland and lowland grazing areas) as shown in Fig. 4. Data on scientific names of grasses and herbaceous species, fresh and dry weight of the fodder sample, coordinates were recorded from the study site. The dry weight was obtained after harvesting the fresh grasses and measure them, then after oven drying the samples were measured again. The plant species were identified by a botanist and through guide books. To assess the rangeland condition, the above-ground biomass was estimated by measuring the dry weight of identified grass species (Tetemke *et al.,* 2019; Zhou & Hemstrom, 2009). The grasses and herbs were oven-dried at 70℃ for 48 h (Sibanda *et al.,* 2017; Stanisavljević *et al.,* 2014). The aim was to determine the diversity, total abundance, and above-ground biomass of fodder species.

To measure the diversity, Shannon-Wiener index of diversity was calculated as shown in Equation 2 modified from (Hammer *et al.*, 2001; Mligo, 2018).

$$H' = \sum_{i=1}^{R} pi\ Inpi \qquad (2)$$

Where H' is Shannon diversity index, *Pi* is the proportion of individual plant species, and *R* is the total number of plant species in an ecosystem. *i* = individual species; N = is the total number of individuals in the community; *ln* = is the natural log and, ∑= is the sum of calculation.

3.3.2 Data Analysis

The analysis was based on fodder collected from two agro-ecological zones (the highlands and lowlands). The analysis and comparison of study sites data was based on 10 subplots in highlands and 10 subplots in lowland agro-ecological zones. All statistics were done by using R software version 3.6.0 (Team, 2013). Descriptive statistics (Mean±SE) were analyzed utilizing Mann Withney U test or Wilcoxon rank sum test with continuity correction.

3.4 Determinants of Households' Fodder Accessibility, Conservation and Motives to Invest on Fodder Production

3.4.1 Sampling Design and Data Collection

A structured questionnaire (Appendix 1) was administered to respondents representing 210 households from the three wards. The total number of households selected for the survey was 70 per ward from 4200 households population representing a sampling fraction of 5% based on Angelsen (2012). The questionnaire was first pre-tested in 15 agro-pastoral households in Sukuma village before the actual household survey. In each ward (Nyigogo, Kahangara, and Lubugu), two villages were randomly selected as a representative sampling area in each ward (Angelsen, 2012).

The criteria for enrolling the households into the study included household engagement in pastoralism or agro-pastoralism activities, and have permanent residence in a particular village for more than five years. The village register together with local leaders were used to identify households satisfying the fore-mentioned criteria. Later, qualifying households were subjected to random selection (simple random sampling) for survey. Households' heads were

directly involved as respondents because they are the key decision makers at the households (Meertens & Consult, 2016). Focus group discussions (FGDs) guide (Appendix 2) were used to collect data from key informants concerning fodder accessibility, conservation and the perception of farmers in investing on fodder production in the study area. The discussion was conducted through official meetings with village leaders. One FGD was conducted in each ward which included a total of 15 participants with broad understanding specific knowledge or interest on the subject matter such as the head of department of District Livestock and Fisheries Officer (DLFO), rangeland manager, 3 ward livestock officers, 6 village livestock officers, 3 Ward Executive Officers and 3 representatives from different fodder production projects.

3.4.2 Variables Hypothesized to Influence the Dependent Variables

The study hypothesizes that households with higher assets including income, landholding, and land size, and socio-cultural settings including education, gender, and native house head would influence fodder accessibility and conservation in the study area (Table 1). Concerning the motives to invest on fodder production, the study hypothesized that households' (income, education, gender, land size, and household size, landholdings, and number of livestock) would influence people to invest in fodder production (IFP) (Omollo *et al.*, 2018; Singh *et al.*, 2014). The study also assumed that household heads with large herd size would be more interested in livestock feed (ILF) accessibility and conservation than those with small herd sizes. Also, the study assumed that educated house heads are more interested in environmental protection (IEP) than less educated house heads (Table 2).

Table 1: Variables hypothesized to influence fodder accessibility and conservation

Variables	Description	Expected influence	
		Accessibility	Conservation
Education	Education of the house head (No formal education = 0; Primary = 1; Secondary = 2; College = 3)	+	+
Gender	Gender of the house head (Male = 1; Female = 0)	±	+
Income	Household daily income in US$ (0.00-2.17 = 0; 2.61-4.34 = 1; 4.78-above = 2)	±	+
Landholding	Land owned by the household (Yes = 1; No = 0)	+	-
Land size	The size of land owned by household ((0.2-4ha) = 0; (5-49) = 1; (50 above) = 2)	+	-
Livestock	Number of livestock owned by household (1-10) = 0; (11-40) = 1; (41 above) = 2	+	-
Native house head	The household head place of birth (Yes = 1; No = 0)	+	+

Source: (Haile, 2019)Note: 1 US$ = 2303.00 TZS
(+) means positive influence; (-) means negative influence

Table 2: Variables hypothesized to influence household interest in fodder production

Variables	Description	Expected influence		
		IFP	ILF	IEP
Education	Education of the house head (No formal education = 0; Primary = 1; Secondary = 2; College = 3)	+	+	+
Gender	Gender of the house head (Male = 1; Female = 0)	+	+	+
Income	Household daily income in US$ (0.00-2.17 = 0; 2.61-4.34 = 1; 4.78-above = 2)	+	+	+
Landholdings	Land owned by the household (Yes = 1; No = 0)	+	+	-
Land size	The size of land owned by household (0.2-4ha) = 0; (5-49) = 1; (50 above) = 2)	+	+	-
Household size	The number of people living in household (Small (1-3) = 0; Medium (4-7) = 1; Large (8 above) = 2)	+	+	-
Number of livestock	Total number of livestock in the household (1-10 = 0; 11-40 = 1; 41 above = 2)	+	+	-

3.4.3 The Choice of a Parametric Model

The choice of the model in this study was grounded on the nature of the dependent variable and the objective of the study. Logistic regression analysis was used to predict the positive or negative influence of the explanatory variables (age, gender, marital status, occupation, educational level, number of livestock, landholding, household size, physical capital (items in the household); and land size) on the households' accessibility of fodder, conservation of fodder sources and the motives to invest on fodder production. Therefore, the behavioural model defined in the equations below is used to assess the factors influencing the households fodder accessibility, conservation and interest to invest on fodder production as described by Berger (2017) in Equation 3.

$$\text{Log odds ratio} = \alpha + \beta_1 \times X_i + \cdots + \beta_n \times X_n + \varepsilon \qquad (3)$$

Where α is the intercept, β is the regression coefficient, Xi is the first predictor or explanatory variable, Xn is the last predictor or explanatory variable, and ε is the random error term. The coefficient β shows the predicted change in the log(odds) for every one-unit increment of a given predictor (x). Equation 3 described the logit(P) as the natural log of the odds ratio (Equation 4).

$$\text{Logit(P)} = \ln(\text{odds}) = \ln\left[\frac{P}{1-P}\right] \qquad (4)$$

3.4.4 The Model Building Process

Six models were generated from eleven predictors. The models include; (fodder accessibility during the dry season, fodder accessibility during the wet season, conservation measures, interest to invest on fodder production, interested in livestock feed and interest in environmental protection). According to Daoud (2018), multicollinearity is very important to ensure the independent variables used in the logit model do not correlate with one another. Therefore the test of the variance inflation factor (VIF) was conducted to ensure the suppressor variable was not more than 5 as proposed by Akinwande *et al.* (2015). Following the test, only variables that indicated the VIF value below five during analysis were used to obtain a thrifty model (Schreiber-Gregory & Bader, 2018). Eleven predictors were used to build the models on the factors influencing households' fodder accessibility, conservation and motives to invest on fodder production. Further, the likelihood ratio, chi-square, and *P*-value were tested to get a well-fitted model (Cleary & Angel, 1984; Daoud, 2018). A value with a high chi-square and a *P*-value <0.05 indicated a well-fitted model. The *pseudo* R^2 of each model was calculated to determine the predictive power of the models (Berger, 2017).

3.4.5 Data Analysis

This study employed ordinal ordered probit regression analysis (multinomial) to analyse the factors influencing the accessibility of fodder sources in dry and wet seasons. Binary logistic regression was used to analyse conservation measures and the households' motives to invest on fodder production since the dependent variables were having the dichotomous outcomes. For the selected socio-demographic characteristics of the sampled households descriptive (including means, standard deviation (SD), frequencies and percentages) and inferential statistical were done using the R software version 3.6.0 (Team, 2013). Table 3 presents variables used for both descriptive and inferential analyses for the household data.

Table 3: Variables used for analysis

Variables	Measurement
Response Variables	
Fodder accessibility in the dry season	Low = 0; Moderate = 1; High = 2
Fodder accessibility in the wet season	Low = 0; Moderate = 1; High = 2
Conservation measures	Effective = 1; Less effective = 0
Interest to invest	Yes = 1; No = 0
Interested in livestock feed	Yes = 1; No = 0
Interested in environmental protection	Yes = 1; No = 0
Explanatory Variables	
Age	18-35 = 0; 36-60 = 1; 61 above = 2
Gender	Male = 1; Female = 0
Education level	No formal education = 0; Primary = 1; Secondary = 2; College = 3
Household daily income	0.00-2.17 = 0; 2.61-4.34 = 1; 4.78-above = 2
Landholdings	Yes = 1; No = 0
Household land size	(0.2-4ha) = 0; (5-49) = 1; (50 above) = 2
Number of livestock	(1-10) = 0; (11-40) = 1; (41 above) = 2
Household size	Small (1-3) = 0; Medium (4-7) = 1; Large (8 above) = 2
Physical capital	Low (0-5) = 0; Moderate (6-15) = 1; High (15 <) = 2
Main income source	Agro-pastoralism = 2; Livestock keeping = 1; Others = 0
Native house head	Yes = 1; No = 0

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Fodder Types, Diversity and Aboveground Biomass of Forage Species

The fodder species found in the study area were natural pastures including (grasses, and legumes), crop residues mainly maize stover, rice straw, and wheat straw. Natural pastures were found in uncultivated public lands such as play grounds, Kidatu electrical line, hills (Ngitiri), and on roadsides. Livestock fodders were mainly obtained from croplands, road sides, open lands, and Ngitiri areas. In particular, this study found that most of the agro-pastoralists (71%) obtain fodder from open areas for free with few (14%) purchasing on the market (Fig. 4).

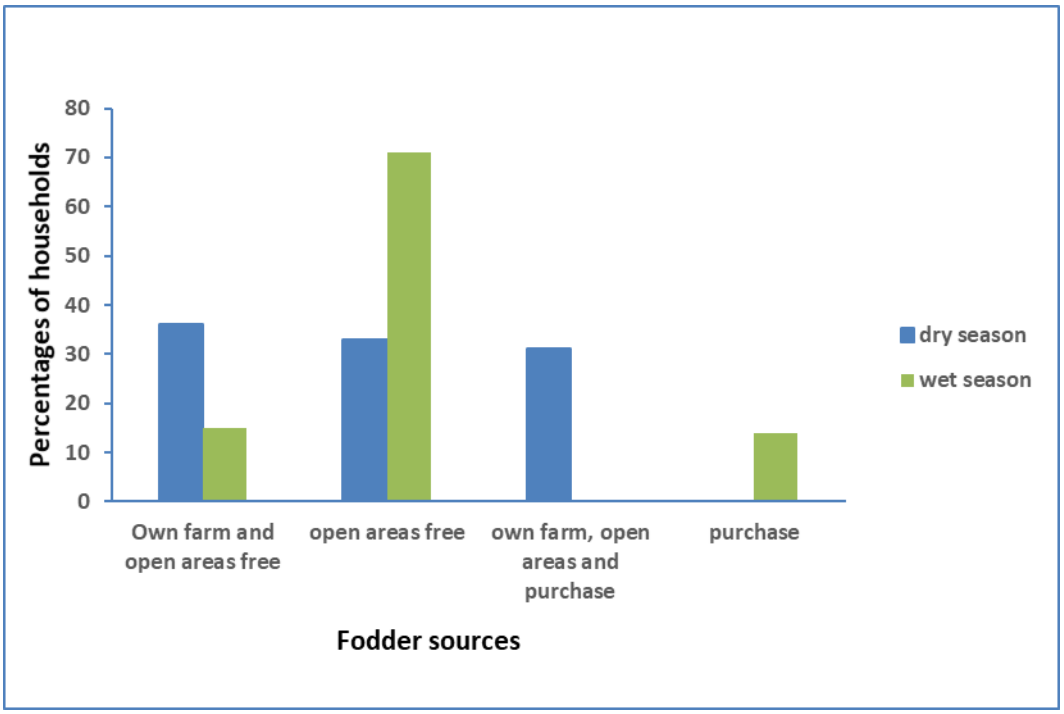

Figure 4: The areas (fodder sources) where agro-pastoralists obtain fodder during the dry and wet season in Magu district, Tanzania

4.1.2 Abundance and Diversity of Fodder Species Found on The Study Areas

A total of 11 forage species were found in the study area. These species include (giant thatching grass or jaragua) *Hyparrhenia rufa*, African star grass (*Cynodon plectostachyus*),

(palisade grass) *Brachiaria,* (buffel grass) *Cenchrus ciliaris,* (Bermuda grass) *Cynodon dactylon,* (Finger millet) *Eleusine coracana,* (Guinea grass) *Megathyrsus maximus*, Nutgrass (*Cyperus rotundus*), Oat grass (*Arrhenatherum elatius*), (Giant rat's tail grass) *Sporobolus pyramidalis,* and (Butterfly pea) *Clitoria ternatea.* The findings of this study revealed that there are no significant differences in diversity and relative species abundance between the two agro-ecological zones (p = 0.009 and Z = 45.5) (Table 5). However, the results show the significant differences in the diversity of fodder species between the agro-ecological zones. The lowland zone shows high diversity compared to the highland zone (Fig. 5). Also, the findings show there is significant difference in abundance between the highland zones and the lowland zones whereby the lowland has more abundance than the highland areas (Fig. 6). In addition, the correlation between the diversity and abundance of fodder species indicated a strong positive relationship of R^2 = 0.99 for the highland and lowland zones (Fig. 7).

Table 4: Diversity and abundancy of fodder species within the agro-ecological zones in Magu district, Tanzania

	Agro-ecological zones (Mean ± SE)			
Variables	**Highland (reserved)**	**Lowland (open)**	**Z- value**	**P- value**
Diversity	0.76±0.22	1.02±0.24	45.5	0.0088
Abundance	2.20±0.20	2.85±0.15	45.50	0.0088
Sample size (N)	10	20		

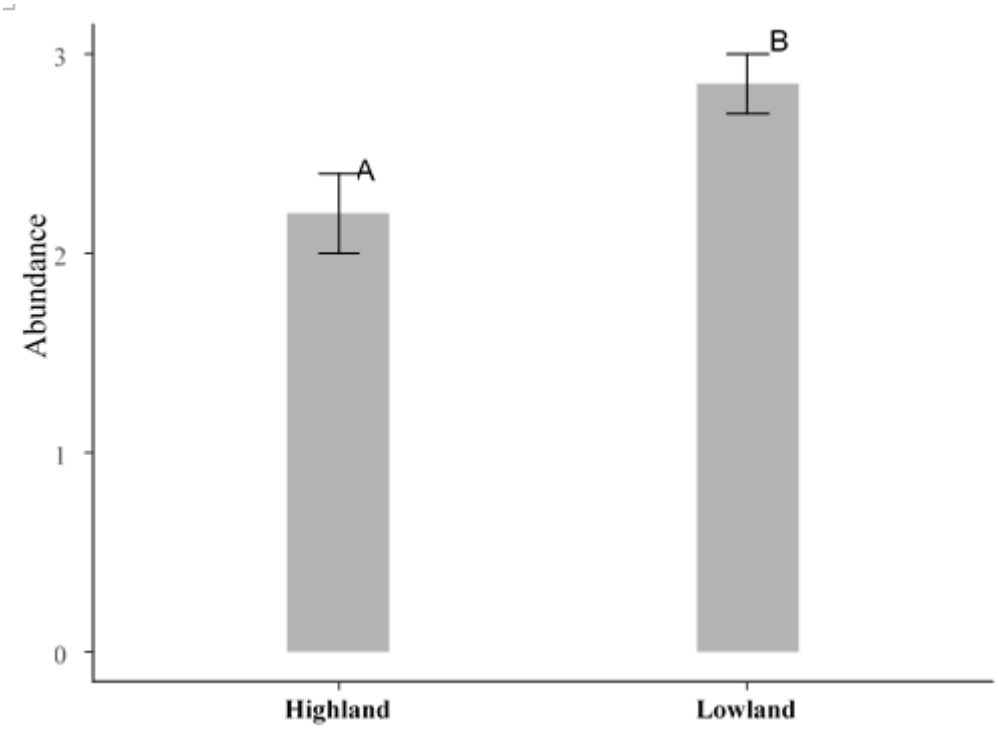

Figure 5: **Mean (±SE) abundance of the fodder species in the study area compared between the highland and lowland agro-ecological zones. Letters on the bars illustrate the significant differences between the two sites at p < 0.05 based on Mann Withney U test (N=30)**

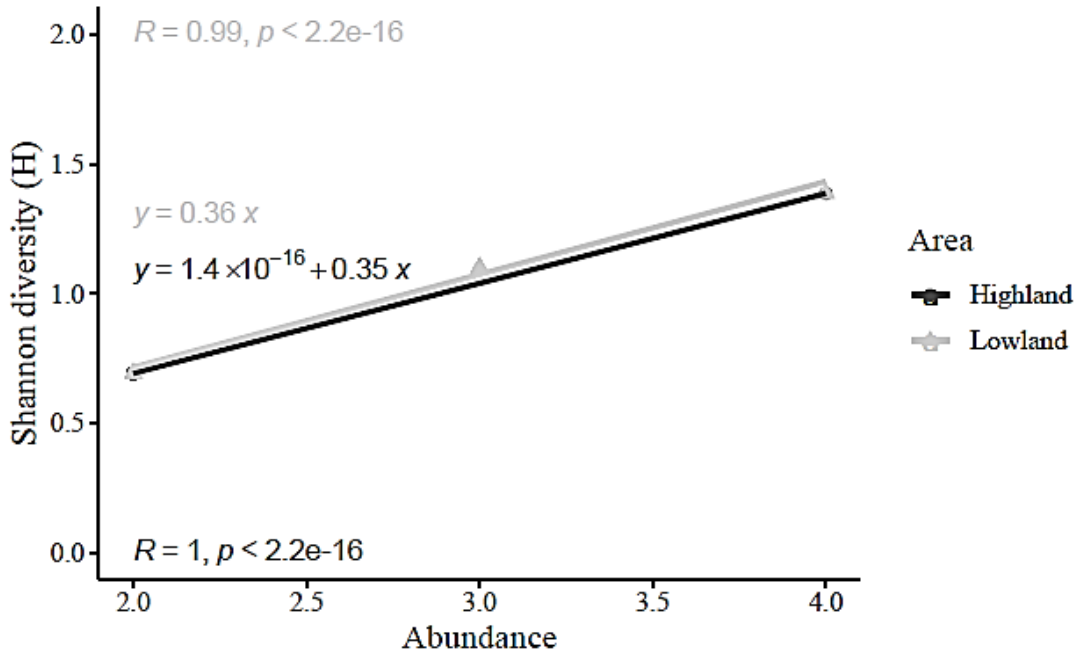

Figure 6: **Correlation between Shannon diversity index and the abundance of fodder species in the study area between in highland and lowland zones at Magu district (N=30)**

4.1.3 Aboveground Biomass and Diversity of Fodder Species Found on the Study Areas

The results of this study indicate that, there is no significant differences on the biomass between the highland and the lowland zones p = 0.3006, W = 124 (Fig. 7). However, the result shows a weak negative relationship between the diversity of fodder species and the biomass on the highland and lowland sites R^2 = -0.13 (Fig. 8). The weak relationship implies there is no significant relationship between the species diversity and the biomass of the fodder species p = 0.59.

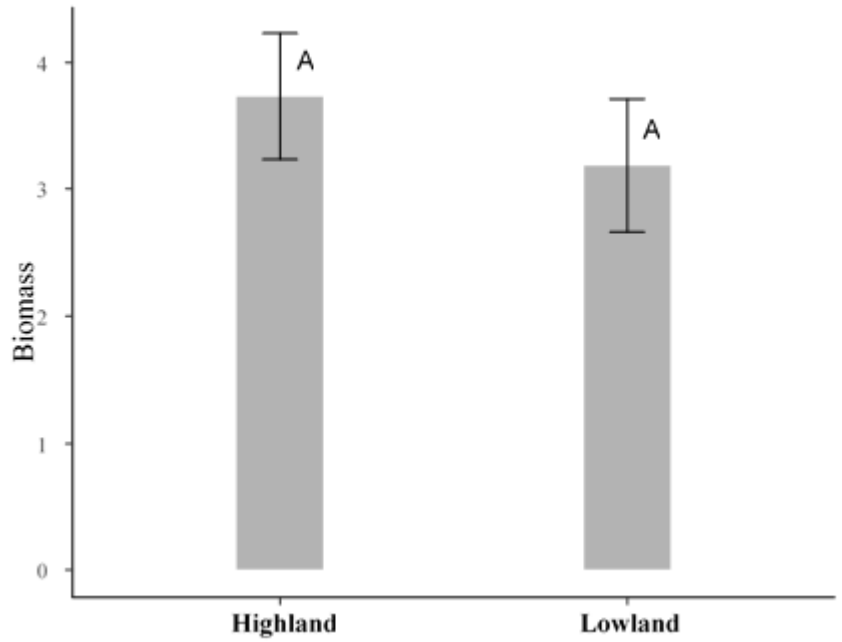

Figure 7: Mean (±SE) biomass of the fodder species in the study area compared between the highland and lowland zones. Letters on the bars illustrate the significant differences between the two zones at p < 0.05 based on Mann Withney U test or Wilcoxon rank sum test with continuity correction (N = 30)

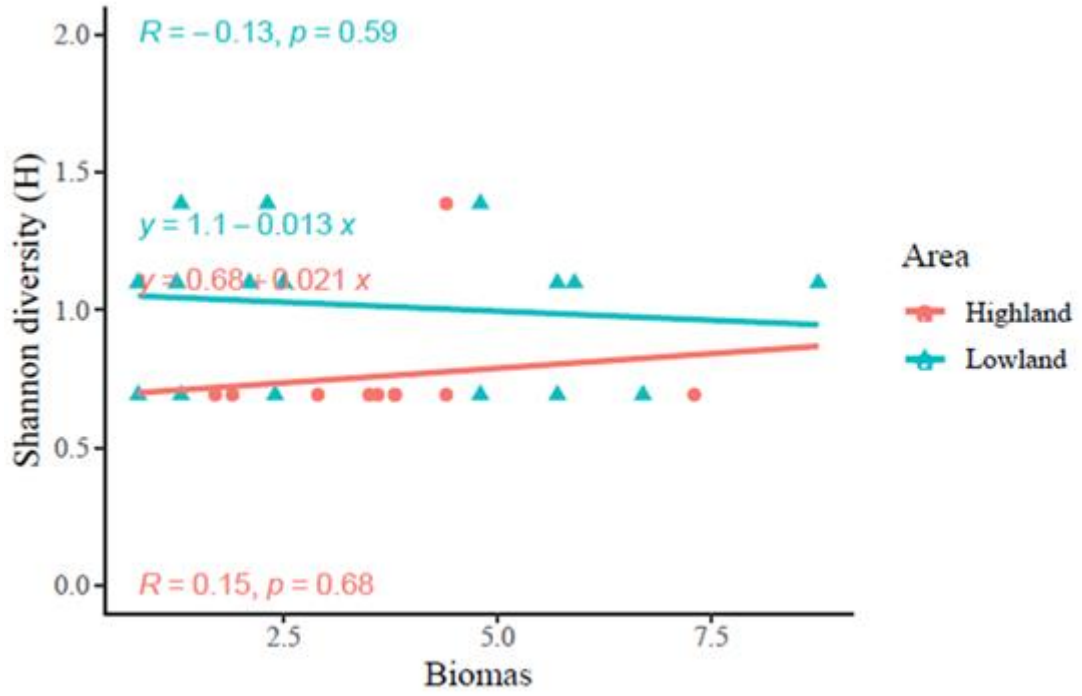

Figure 8: Correlation between Shannon diversity index and the biomass of fodder species in the study area between in highland and lowland zones (N=30)

4.1.4 Socio-Economic Characteristics of Households

The age of the respondents ranged between 18 and 87 years. The majority of respondents (44%) were under the age group of 36–60 years (Table 4). Out of total respondents, 7% were illiterate (unable to read and write), 9% had secondary education, 3% had college and university education while the majority 81% had primary education. Majority of the respondents (78%) are depending on agro-pastoral activities as households' source of income, while 14% are depending on pastoralism with the average number of 20 livestock per household. In addition, 8% of the respondents are depending on other activities such as fishing, entrepreneurship, carpentry, and salary/wages. The average household size comprised 6 individuals and the average land holding size was 5 ha.

Table 5: Socio-economic characteristics of households' respondents in the study area

Variable	Category	Responses	
		Frequency	Percentages (%)
Gender	Male	155	74
	Female	55	26
Age	18-35	58	27
	36-60	92	44
	61 <	60	29
Education level	Illiterate	15	7
	Primary	171	81
	Secondary	18	9
	College/University	6	3
Income source	Agro-pastoral	164	78
	Livestock keeping	29	14
	Others	17	8
Land holding size	(< 4 ha)	106	50
	(5-49 ha)	100	48
	(> 50 ha)	00	00
Household size	Small (1-3)	44	21
	Medium (4-7)	121	58
	Large (> 8)	45	21
Number of livestock	1-10	46	22
	11-40	123	59
	41<	41	19

4.1.5 Household Fodder Accessibility

Age, gender, size of land, number of livestock, income source, education, household size, physical capital, and household head place of birth predict a positive influence on the accessibility to fodder (Table 6). The results revealed that 65% of the household access fodder sources formally in open areas while 35% access informally in reserved highlands areas, crop fields, and restricted urban areas (Fig. 9). The results also showed a positive and significance influence (p = 0.05) that male headed households were more likely to access fodder than the households headed by females (Table 6).

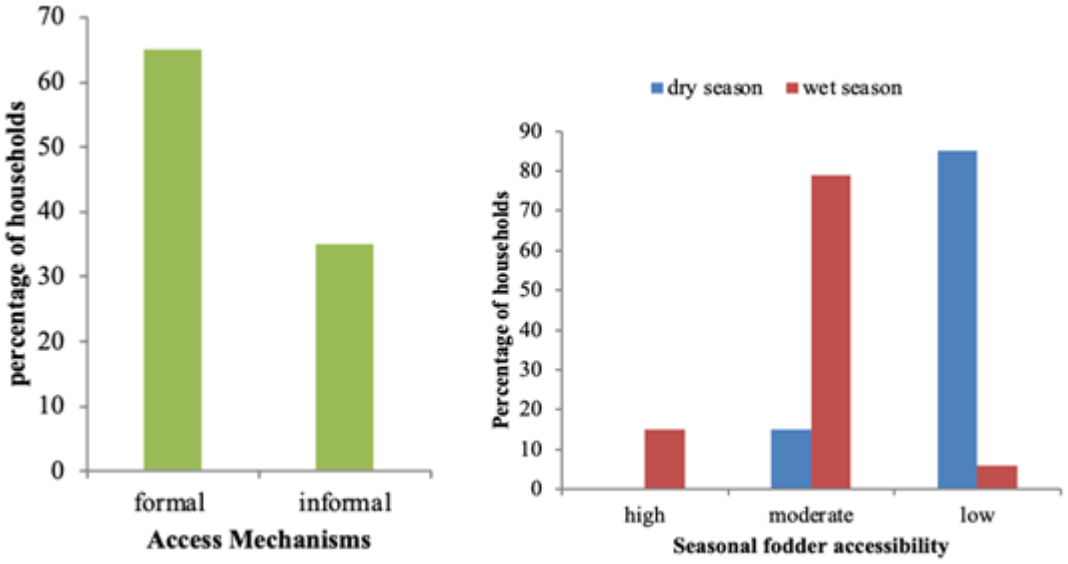

Figure 9: Percentage of households that responded to the mechanisms used to access fodder and the status of fodder accessibility during dry and wet seasons considering three measured factors (high, moderate, and low)

Households' socio-economic characteristics such as household head gender and education level, household size, household head place of birth, and household income recorded a positive relationship with the availability and accessibility of fodder in the dry season (Table 6). However, during dry season, 15% of the agro-pastoral households are likely to access livestock feed in moderate amount, while 85% of the households access the feed in a very low amount (Fig. 9). The results also revealed a negative relationship between access to fodder and characteristics of the household including age (36-60), landholding, and income source (Table 6). Households' land size, physical capital and the number of livestock (p = 0.000; p = 0.027; p = 0.075 respectively) recorded negative significant correlation with access to fodder during the dry season (Table 6).

Fodder accessibility by households during wet season was positively influenced by household's income, land size, household size, and number of livestock, income source, physical capital, gender, and the household head place of birth (native household head) (Table 6). Number of livestock, household land size and physical capital was recorded to have positive and significance (p = 0.009, p = 0.083, p = 0.002 respectively) influence on fodder accessibility during the wet season. During the wet season, the results showed that 15% of the households access a high amount of feed, while 79% of households can access an average amount of feed. However, only 6% of households reported very low amount of feed

(Fig. 9). The results also showed that there was a negative correlation between household (age and level of education) and the availability of fodder during the wet season (Table 6).

4.1.6 Conservation of Fodder Sources by the Households

There was a positive relationship between income, gender, education, number of livestock, land size, household size and physical capital with conservation of fodder sources (Table 6). Households' income, household land size and education level showed a positive significant relationship ($p < 0.10$, $p < 0.008$, $p < 0.002$ respectively) with conservation of fodder sources. More than 40% of households were likely to conserve the fodder sources while 58% of the agro-pastoralist households were not taking any conservation measures (Fig. 10). The results revealed that heads of households with secondary and tertiary (college/university) education were more likely to conserve the fodder sources than their counterparts. The results also indicated a positive relationship between gender and fodder conservation. Males were more associated with conservation of fodder than females. However, the findings showed a negative correlation between households' landholding, native house head, income source, and age with conservation of fodder sources (Table 6).

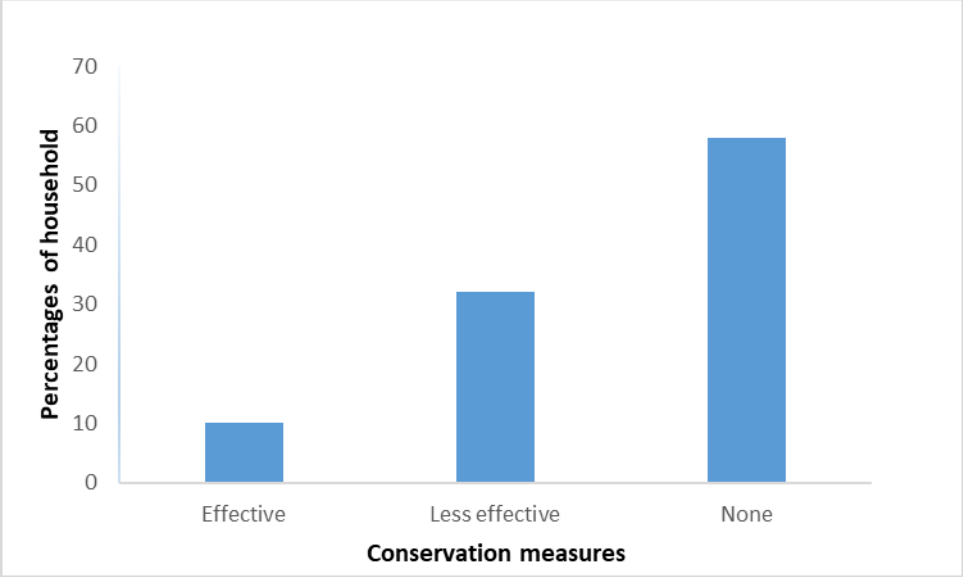

Figure 10: Percentage of households that responded to the conservation measures which are taken by the community members to conserve the fodder sources

Table 6: Marginal effect estimate of the influence of the socio-economic factors on fodder accessibility and conservation of fodder sources

Variables concerning the house head	Access in dry season	Access in wet season	Conservation measures
Age (36-60)	-0.055(0.638)	-0.345(0.221)	-0.000(0.166)
Age (61 above)	0.199(0.767)	0.120(0.207)	-0.008(0.142)
Gender (Male)	2.636(2.596)	1.377(0.184)	0.007(0.053)
Household size	0.097(0.102)	0.027(0.076)	0.059(0.057)
Household daily income	1.075(0.864)	0.067(0.025)	0.208(0.399) **
Education (college)	3.625(2.258)	-0.459(1.290)	3.625(1.260) **
Education (primary)	2.829(2.035)	-0.179(1.052)	1.239(0.678)
Education (secondary)	2.374(2.318)	-0.367(1.326)	1.239(0.068) *
Household land size	-0.316(0.094)***	0.089(0.047) **	0.070(0.037)**
Number of livestock	-0.023(0.016)**	0.225(0.048)***	0.001(0.010)
Source of income (Agro pastoralist)	0.154(0.877)	0.435(0.034)*	1.007(0.015)
Source of income (livestock keeping)	-0.767(0.871)	0.588(0.058)	-0.261(0.031)
Landholdings	-0.003(0.061)	-0.058(0.047)	-0.052(0.037)
HH born in the village	0.476(0.564)	0.287(0.217)	0.151(0.138)
Physical capital(low)	-2.448(1.247) **	-0.090(0.219) **	0.411(0.881)
Physical capital(moderate)	-3.046(1.220) **	1.460(0.221) **	0.035(0.846)
Likelihood ratio (Chisq)	65.37***	109.35***	176.00**
Pseudo R-square	0.6784587	0.4335437	0.289003

Statistical significance codes: $***p \leq 0.01$ $**p \leq 0.05$ $*p \leq 0.10$ (p is the alpha level). The numbers in parenthesis are the standard errors

4.1.7 Household Interest to Invest in Fodder Production

This study reveals a positive relationship between households' (gender, age, income, land size) and the interest of people to invest in fodder production. Majority of the agro-pastoralists (97%) were interested and demonstrated the willing to invest on fodder production while, only (3%) were not interested. Concerning the motives to invest in fodder production; 56% of agro-pastoralists households were interested to invest in fodder conservation to allow them benefit by having secure source of livestock feed while 44% were not interested in livestock feed (Fig. 11). However, the results showed a positive relationship

between households' gender, education level, land size, number of livestock, income source, and low physical capital and the interest to invest in fodder production in order to benefit from livestock feed (Table 7). About 41% of households' interest in protecting their environment apart from benefiting from livestock feed (Fig. 11). Further, the results show a positive influence between households' (income, education, land size, landholding, native house head) and the motive to invest in fodder production for aim of protecting the environment (Table 7).

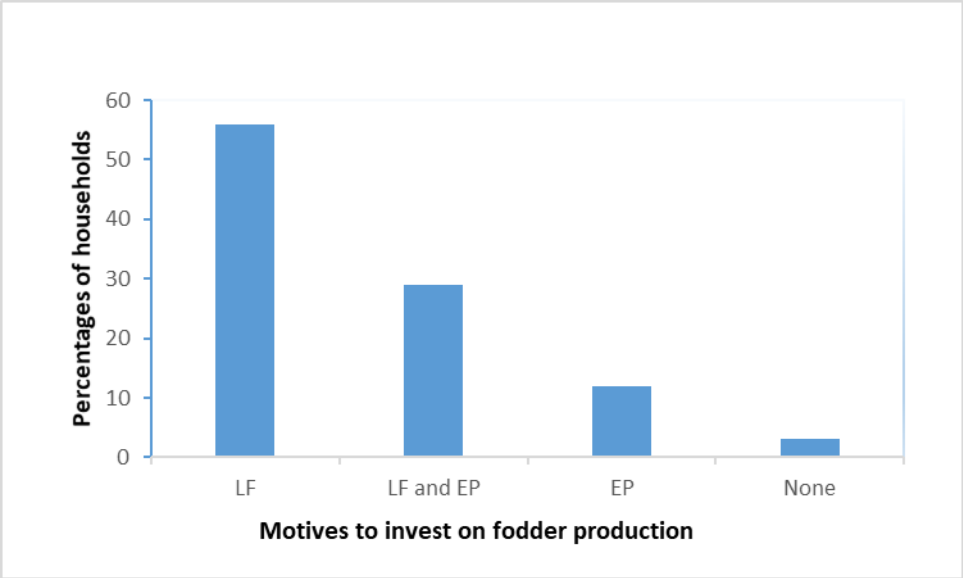

Figure 11: Percentage of households that showed interest in the factors (LF= livestock feed only, LF and EP=livestock feed and environmental protection, EP=environmental protection only, and none=not interested in any) that motivates people to invest in fodder production

Table 7: Marginal effect estimate of the influence of the socio-economic factors on households' interest to invest on fodder production

Variables concerning the house head	Interest to invest	Interested in EP	Interested in LF
Age (36-60)	0.002(0.003)	-0.314(0.211)	0.072(0.536)
Age (61 above)	-0.442(0.003)	1.378(0.184)	-1.518(0.578)
Gender (Male)	0.002(0.000)**	-0.077(0.001)	0.067(0.010) *
Household size	-0.054(0.030)*	-0.008(0.011)	-0.354(0.956)
Household income	0.018(0.000)	0.018(0.000)	-0.032(0.002)
Education (college)	-0.023(0.000)	0.002(0.001) *	-0.016(0.011)
Education (primary)	-0.018(0.000)	0.076(0.001) **	0. 470(0.837)
Education (secondary)	-0.020(0.000)	-0.083(0.002)	0.001(0.001)
Household land size	3.897(2.180)***	1.056(0.630)	0.783(0.559)
Number of livestock	-5.616(4.523)	-0.005(0.139)	0.110(0.120)
Source of income (Agro pastoralist)	-0.03(0.003)	-0.050(0.758)	0.001(0.754) ***
Source of income (livestock keeping)	-0.001(0.003)	-0.1311(0.972)	0.001(0.910) **
Landholdings	-0.019(0.000)	0.016(0.041) **	-0.159(0.001)
House head born in the village	-0.311(0.001)	1.862(0.562)	0.164(0.474)
Physical capital (low)	-0.411(0.881)	-1.350(0.121)	0.15(0.908)
Physical capital (medium)	-0.035(0.846)	0.010(0.215)	-0.656(0.603)
Likelihood ratio (Chisq)	22.82*	75.75**	86.40**
Pseudo R-square	0.5720244	0.218743	0.5023273

Significance codes: ****P ≤ 0.01. ** P ≤ 0.05. * P ≤0.10* (P is the alpha level)

The numbers in parenthesis are the standard errors.

4.2 Discussion

4.2.1 Fodder Species, Diversity and Aboveground Biomass of Forage Species

The findings of this study revealed that highland agro-ecological zone few (36%) forage species cover than the lowland site which was covered by (67%) of forage species. However, the findings indicated the significant differences in the diversity and abundance of fodder species between the highland and lowland zones with the later zone showing high diversity and high relative abundance compared to the highland zone. This could be attributed to easy accessibility of fodder on the lowland zones because grazing areas are open access for livestock keepers in both dry and wet seasons compared to highland (Ngitiri) where the areas were traditionally enclosed during the wet seasons (Kamwenda, 2002; Selemani *et al.*, 2013). Easy access on the lowland areas results to frequent movement of livestock which may lead to dissemination of fodder seeds from one area to another and thus, leading to high diversity (Islam & Ashilenje, 2018). These findings corroborate with earlier studies e.g., by Egeru *et al.* (2015) on the study done in Karamoja pastoral community, Uganda on native forage species documented that species diversity index observed in the area was caused by transfer of species from one grazing area to another. A study by Mohammed *et al.* (2021) also show that the low species diversity on the grazing areas is highly associated with the informal access of fodder sources and intensive livestock grazing.

This finding suggest the need to introduce strategies for pasture management to enhance the diversity of fodder species in the fodder sources as suggested earlier by Sanderson *et al.*, (2007). Also, intervention practices to the farmers through practicing fodder crop plantation to increase the species diversity and abundance (Hassa, 2018; Peters *et al.*, 2001; Tracy & Sanderson, 2004). Furthermore, the increase of fodder diversity will enhance the ecosystem sustainability on rangelands, availability of fodder resources and hence increase livestock production. The strong positive relationship between the species diversity and abundance of fodder species for the highland and lowland zones indicates the increase of individual species influences the diversity of species in both lowland and highland zones (Schaub *et al.*, 2020). Therefore, the there is a need to diversify fodder production in the agro-pastoral community to enhance the availability of adequate and quality fodder for livestock production.

Also, the study shows that, above ground biomass in the lowlands decreased with increasing species diversity. This implies that, the amount of biomass is direct proportional with species

diversity. This indicates that, the grazing area has poor production which is mainly attributed by grazing pressure with poor soil fertility which lead to slow species recovery (Selemani *et al.*, 2013; Zhou & Hemstrom, 2009). The low aboveground biomass is associated with poor livestock production as a result of inadequate feed resource (Crop *et al.*, 2016; Sibanda *et al.*, 2017). On the highland site the aboveground biomass increases with the increase of species diversity which indicated that, the traditional management of grazing areas (highland/Ngitiri) has the promising result on the recovery of the grazing areas compared to the open or free grazing areas (Kamwenda, 2002). However, the findings from the study by Selemani *et al.* (2013) reported that the recovery of vegetation of rangelands is very slow and therefore, to enhance the availability of adequate livestock feed, the production of fodder is needed. Further, this finding suggests the need to encourage intensive management of fodder species (grasses and herbaceous) in order to facilitate the diversity and increase the rangeland productivity. This could be linked to the study by Schaub *et al.* (2020) which postulates that, plant diversity and biomass yield was high for intensively managed pasture lands than the less managed ones which ensured high plant diversity in the managed pasture land.

4.2.2 Household's Fodder Accessibility and Conservation of Fodder Sources

The results show that, household income has a positive influence on fodder accessibility during the dry season. This implies that, households with higher income can diversify fodder sources by e.g., purchasing in the market, neighbouring farms and own farms. Whereas households characterized with low income depend mainly on the free-range open areas such as road sides, playgrounds, field farms and from the neighbours' farms. This study is similar to Maleko *et al.* (2018), Tolera and Abebe (2007) and Sala *et al.* (2020), who documented that annual household's income plays an important role in determining fodder availability and accessibility in harsh climatic conditions. On the other hand, this study reveals that household heads' education level has positive influence on the accessibility of fodder during the dry season. Omollo *et al.* (2018) also report that farmers who had higher education levels and the ones engaging themselves in training associations were more likely to participate in the production of fodder than their counterparts. Olila and Tambo (2014) also argue that farmers' knowledge and awareness creation is one of the important pathways of ensuring the sustainable production of livestock in the agro-pastoral societies.

Accessibility of fodder during the wet season was positively influenced by the households with high assets such as income, land size, physical capital, and number of livestock, as well

as socio-characteristics including household size and the household head place of birth. This implies that although the availability of fodder during the wet season is high compared to the dry season (Ernest *et al.*, 2017; Mtengeti *et al.*, 2008), grazing during the wet season is limited because larger part of land is utilized by farmers for cultivation of food crops. The shortage of land for fodder during the wet season is mainly caused by the overlap of cropping seasons and the need to diversify livestock feed through the enclosure management system of the (traditionally reserved lands) locally known as *Ngitiri*. A study by Kamwenda (2002) and Selemani *et al.* (2013) in semi-arid areas in north-western Tanzania also show that livestock pastures during rainy season becomes limited especially on the traditionally reserved *(Ngitiri)* areas. Therefore, the farmers can only access fodder in the open lands, crop lands, and along the road sides.

The findings from this study revealed further that, during wet season households with higher assets (income, land size, household size, number of livestock, physical capital), can easily access fodder than the poor asset households. Households with higher assets can access fodder from different sources including purchasing from the market and even to access the livestock feed from far areas by ordering through a vehicle, bicycle, or motorbike (Rai, 2018). Zimmer *et al.* (2021) indicated that the availability of forage increases in favourable seasons of the year compared with the observations made during unfavourable seasons. Therefore, our results reinforce the government and non-government actors to facilitate the understanding of inherent variability in fodder availability during the two rainy seasons that can improve management options of the sources of feed and avoid overutilization of feed during the dry season.

The study also indicated a positive relationship between household income and conservation of rangelands. The households with high income were likely to be advantages in conservation of the fodder sources over the households characterized by low income. This is because households with high income have a wide chance of fodder conservation measures, including enclosure system that leaves the rangeland to regain its nature (paddock) and rotational grazing of the available rangelands (Kariuki, 2018; Selemani *et al.* 2013). The findings of this study echoes a study by Peters and Lascano (2003) which show that households with high income can easily access fodder conservation technologies to increase and/or improve feed (for dry or winter season) sources. Whereas households with low income can only access

livestock feed from natural foraging and crop residues (Roy & Singh, 2008; Selemani *et al.,* 2013).

The results also show that education level have significant influence on the fodder conservation measures by the households. Educated households are more probable to conserve the fodder sources than the less educated households. Adoption of different farming management practices Gessesse *et al.* (2016), new technologies (Yeneayehu *et al.,* 2019), by farmers is determined by the education status. Educated household heads have better insight and reasoning ability to understand the benefits of participating in conservation of fodder sources (Moges & Taye, 2017; Wairore *et al.,* 2015). Therefore, there is an urgent need to pragmatic development and conservation strategies with education as its core.

4.2.3 Households' Interest to Invest in Fodder Production

The study positively predicts the possibility that more than 90% of male headed households were more interested to invest in production of livestock feed than their counterparts. The age group of 36-60 are also more interested to invest in fodder production than their other counterparts. This can be caused by awareness and wealthy of this age group in terms of income, land size, and the number of livestock they have. The findings are similar to Masuku and Xaba (2013) and Meijer *et al.* (2015) who reported that older group of farmers were more likely to engage in fodder production activities than the young age group due to the experience the former have in agriculture. This study suggests that the need for awareness campaigns to focus on youth to enhance youth participation in fodder production and conservation.

Likewise, household assets show a positive relationship with the individual's interest to invest in fodder production. This implies that, households' assets such as landholdings and income have a greater influence on community to invest in fodder production (Moges & Taye, 2017; Omollo *et al.,* 2018). This results corroborates with the findings documented in Owusu *et al.* (2021) which show that households with higher income were more interested to invest in forest restoration due the perceived forest benefits. Further, the study done in Ethiopia on water and soil conservation technologies by Moges and Taye (2017) reported that, land ownership and plot size positively influenced the farmers to invest and adopt to soil conservation technologies. This study therefore reinforces the need to promote holistic development approaches among agro-pastoral communities especially poorly-resource

endowed households have access to monetary and physical assets to enhance community willingness to invest in fodder production.

The study also show that the agro-pastoral households were motivated to invest in livestock feed. This can be attributed to the scarcity of livestock feed due to unpredictable climate change in the agro-pastoral communities (Maleko, 2020; Mtengeti *et al.,* 2008). This postulates that majority of the agro-pastoral livelihoods are highly dependent on livestock keeping and crop production and therefore they term the livestock as their bank accounts to sustain their livelihood (Kamwenda, 2002; Selemani *et al.*, 2013).

Education level had positive influence on the interest of the community to invest in fodder production. In Magu district, few groups of farmers with fodder knowledge have decided to set apart some portion of their land for fodder crop farming. Likewise, a previous study by Manyeki *et al.* (2015) in Kenya reported that in Makueni, Narok and Mashuru educated household heads were more interested to adopt natural pasture improvement technologies than the less educated household in the same areas. This can be attributed to the ability of educated individual to predict future consequences of having limited access to forage resources (Nkya *et al.,* 2018). This study unveils the need for state and non-state to consider education as an integral part of livestock sector development.

This study reveals further that there is a positive influence between higher asset household (income, land size, land ownership) socio-characteristics (education, native house head) and the motive to invest in fodder production for environmental protection (Table 7). More than 40% of surveyed households show interest to protect their environment apart from benefiting from livestock feed. Asset-rich household have much influence on environmental protection due to the fact that they can easily adapt to the measures to enhance environmental protection such as fodder planting, rotational grazing, and destocking due to their access to land (Gessesse *et al.,* 2016; Masuku & Xaba, 2013; Sala *et al.,* 2020; Yeneayehu *et al.,* 2019). Moreover, the households with many assets have other means of generating income apart from depending only on their primary income sources such as fishing, entrepreneur and office work (Owusu *et al.,* 2021). This increases their interest in environmental protection apart from livestock feed.

The level of education shows a greater influence towards environmental protection. Education level influence decision-making ability of household heads to consider future risks,

creating a greater chance for educated pastoral and agro-pastoral households to diversify their livelihood sources (Okello *et al.*, 2014). The level of education can influence community to grow pasture which can be used as a source of animals fodder while at the same time they create a conducive micro-climatic environment for people around such as annual and perennial pasture, herbs, grasses, and trees (Number *et al.,* 2019). Therefore, fodder knowledge to the agro-pastoral societies is very important as it helps to foster community development basically on environmental protection and livestock production.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study shows that, there is low relative abundance and diversity of grasses and herbaceous fodder that leads to low productivity of rangelands in Magu district. It also shows households' gender, land size, number of livestock, and physical capital have divergent influence on the accessibility of fodder during the dry and wet seasons. Household heads' education and income level have positive influence on households' willingness to participate in conservation of fodder sources. However, households' gender, land size, income source, education level and landholdings motivate agro-pastoralists households to invest on fodder production. Therefore, this study suggests that effort towards the sustainable intensification of livestock production in agro-pastoral communities should focus on improving land tenure rights for women, enhance access to higher education and diversify households' incomes sources.

5.2 Recommendations

(i) Rangeland and livestock management should address issues of proper land use, promoting fodder production through diversifying fodder species in the agro-pastoral community to enhance the availability of adequate and quality fodder for livestock production in Magu district.

(ii) Encouraging pasture management and conservation of fodder sources through intensive management of fodder species would facilitate the diversity and increase rangeland productivity. Also, the government can consider issues of land tenure systems (who owns the land and who has the right to use or to benefit from the land) embroiled in historical and traditional spheres that disadvantages women to improve equality in land ownership.

(iii) Agro-pastoral development policies and reforms should base on site specific socio-economic characteristics to overcome issues of lack of interest driven by poverty and low literacy. Specifically, states actors and non-state actors shall actively engage local communities in developing economically feasible and socially acceptable land use

plans to improve community willingness to adopt and abide by rangelands management strategies.

(iv) Agro pastoralist are advised to invest and adopt fodder production technologies including planting of fodder crops instead of depending only on the natural forage crops. Cultivation of fodder crops would help to increase diversity, availability and accessibility of livestock feed to farmers. Not only that but also, farmers are encouraged to seek knowledge from the experts and participate on training services.

(v) Further research should focus on the enhancing feeding technologies for sustainable agro pastoral livestock production in LVB.

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APPENDICES

Appendix 1: Questionnaire for Household Survey

A: General information

Ward…….....

Village…….....

Sub village……

Telephone number…….

GPS points of reference on household……....

Date of interview……

Respondent information

Name of the respondent……

Age.....

Education level……

Sex……...

Telephone number……...

Household composition

1. Who are the members of this household?

1.Personal Identification number	Name of household member	2. Relation to H. head	3. Age	4. Sex 1=male 2=female	5. Education	6.Income source
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Codes:

2) 1=household head; 2=spouse (legally married); 3=son/daughter; 4=son/daughter in law; 5=grandchild; 6=mother/father; 7=mother/father in law; 8=brother or sister;

9=brother/sister in law; 10=uncle/aunt; 11=nephew/niece; 12=step/foster child; 13=other family; 14=not related (e.g., servant).

5) 1=No formal education; 2=Primary education; 3=Secondary education; 4=Vocational training; 5=College (Diploma/Certificate); 6=University (Degree)

6) 1= Student; 2= farmer; 3=Private Employee; 4= Government employee; 5= Small business; 6= House maid 7= fishermen; 8=other, specify

2. Questions regarding the head of this household.

Question	Responses
i. What is the status of household head? Codes: 1=married and living together; 2=married but spouse working away; 3=widow/widower; 4=divorced; 5=never married; 6=other, specify	
ii. How long ago was this household formed?	years
iii. Was the household head born in this village? 1=no; 2=yes	
iv. If 'no': how long has the household head lived in the village?	
v. How many wives do you have?	number

B: Household assets

3. Do you own land?

0 = No; 1 = Yes

4. How many acres of land you own, rented out and rented in by a household for the past 12 months?

Category of land	Area in acres and area located within Magu district			Total area in acres
	Self-owned	Rented in	Rented out	
Pasture (natural or planted)				
Cropland				
Bare land (not in use)				
other, specify				

5. Do you think the land owned by the household is enough?

0 = No; 1 = Yes

6. Do you have your own house?

0 = No; 1 = Yes

If No skip to other question, if yes please indicate the type of materials used to construct your house(s).

7. How many houses do you own?

house materials			
No. of houses	Code1: walls	Code2: floor	Code3: roof
1			
2			
3			
4			

Codes1: 1=mud/soil; 2=wooden (boards, trunks); 3=iron (or other metal) sheets; 4=bricks or concrete; 5=reeds/straw/grass/fibers/bamboo; 6=other, specify:

Codes2: 1=sand/soil; 2=cement; 3=tiles; 4=wooden floor; 5=rough floor; 6=other, specify

Codes3: 1=thatch; 2=wooden (boards); 3=iron or other metal sheets; 4=tiles; 5=other, specify.

8. Do you own livestock?

0 = No; 1 = Yes

9. What type and number of livestock self-owned and livestock kept but not owned by this household?

Type of livestock	Self-owned inside the household compound	Self-owned but kept outside the household compound	Kept but not owned	Total
1.cattle				
2.goats				
3.sheep				
4.horses				
5.donkeys				
6.pigs				
7.other, specify				

10. What type of machines or vehicles owned by the household?

Machine/vehicle	No. of units owned	Condition of a machine		
		1. working	2.not working	3.needs repair
1. Car/truck				
2. Tractor				
3. Motorcycle				
4. Bicycle				
5. Plough				
6. Wooden cart or wheelbarrow				
7. Water pump				
8. Trailer				
9. Harvester				
10. Other, specify				

C. Crop cultivation

11. Do you practice farming?

0 = No, 1 = Yes

12. What types of crops which are cultivated in this area?

1=maize, 2=paddy, 3=potatoes, 4=cassava, 5=millet, 6=sorghum, 7=beans, 8=other

13. Does your household produce enough food for consumption?

0 = No, 1 = Yes

14. Do you use the crop residues for livestock?

0 = No, 1 = Yes

If No go to item D, but if Yes go to the next question.

15. How do you use the crop residues?

1=Cut and store for future feeding livestock, 2=Feeding livestock the remaining on farm, 3=Selling, 4= Left in the farm for manure, 5=given to other people for free, 6=Not used

16. How do you preserve/store crop residue for future use?

1=Silage, 2=Hay bailed storage, 3=Hay stalk storage in hay store, 4=I don't know, 5=0ther, specify

D. Fodder sources

17. Where do you get fodder for your livestock during wet and dry seasons?

Option areas	Dry season	wet season
1=From own farm		
2=From peoples' farms for free		
3=Purchase from peoples' farms		
4=From forest areas for free		
5=Purchase from forest areas		
6=Open land for free		
7=Purchase on market		
8=other, specify		

18. What are the common fodder sources for livestock?

1 =Natural fodder, 2=Planted fodder, 3= I don't know, 4= other, specify

19. Do you conserve fodder sources?

0 = No, 1 = Yes

20. How do you conserve fodder sources?

1=Rotational grazing, 2= Prescribed burning, 3= Replanting, 4= I don't know, 5= Other, specify

21.Rank the measure you take for conservation

0 = Less effective, 1 = Effective, 2 = None

22. Have you ever purchase fodder?

0 = No, 1 = Yes

23. How much does it cost per bail or per acre?.....

E: Fodder availability and accessibility

24. What is the current fodder situation in your village? (Fill the table below)

1. Fodder situation	2. If it is decreasing what is the reasons?	3. What to be done?

Code1: 1=Increasing; 2=Remaining the same; 3=Decreasing; 4=I don't know

Code2: 1=Shortage of rainfall; 2=Destruction of soil; 3=Shortage of land; 4=Urbanization 5=Lack of capital; 6=overgrazing; 7=other, specify

Code3: 1=Fodder plantation; 2=Giving loans; 3=Applying irrigation system; 4=other, specify

25. Rank the availability of fodder during wet season

0 = low, 1 = moderate, 2 = high

26.Rank the availability of fodder during dry season

0 = low, 1 = moderate, 2 = high

27. Do you suffer fodder shortage from any of the following weather events?

1=Drought, 2=Flooding, 3=Severe wind, 4=I don't know, 5=other, specify

28.What is the mechanism of accessing fodder in reserved areas?

0 = informal, 1 = formal, 2 = I don't know

29. What is the mechanism of accessing fodder in open areas (bushlands, roadsides)?

0 = informal, 1 = formal, 2 = I don't know

F: Drivers to invest in fodder production

30. Fill in the table below

1. Is there any need for you to cultivate fodder crops?	2. If Yes, what are the **push** factors	3.If No, what are the **pull** factors

Code1: 1=No; 2=Yes

Code2: 1=fodder demand; 2=environmental friendly; 3=other, specify

Code3: 1=Knowledge; 2=low fodder cost; 3=Lack of land; 4=lack of fodder seeds; 5=poor soil; 6=lack of labour; 7=other, specify

G: Livelihoods

31. How much do you earn per day?

0 = 0-5000, 1 = 6000-10000, 2 = Above 11000

32. Which of the following activities are the major sources of livelihood? Put rank in order of importance (rank: the first (1) to be the most important source)

Livelihood sources	Rank
Farming	
Livestock keeping	
Fishing	
Tourism	
Business	
Wage and salaries	
Other, specify	

Thank you for your time!

Appendix 2: Focus Group Discussion

1. How does the following factors affect fodder access?

i. Gender……
……

ii. Education……
……

iii. Income……
……

iv. Individual status…….
……

v. Seasons……
……

2. Do you consider the number of livestock when accessing the fodders on Ngitiri areas? Why?

…….

3. What to be done for people to invest in fodder production?

……
……

4. What ways do people use to conserve/protect fodder sources?

……
…… ……...

5.What steps/measures do people take to protect fodder sources?

……
……

6.What are the current challenges facing the agro pastoral societies? What to be done to help address these challenges?

……
……
……

Thank you for your time!

RESEARCH OUTPUTS

Journal Paper

Rustis, G., Hambloch, C., Swamikannu, N., & Moyo, F. (2023). Determinants of Agropastoralist Households' Fodder Accessibility and Rangeland Conservation in Magu District, Tanzania. *Rangeland Ecology & Management*, *87*, 22-29.

Poster presentation

Assessing the accessibility, conservation and production of fobber for livestock for the agropastoral societies in Magu District, Tanzania.

Appendix 3: Poster Presentation

Assessing the Accessibility, Conservation and Production of Fodder for Livestock for the Agro-pastoral Societies in Magu District, Tanzania

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Introduction

- .Livestock contributes about one third of total global agricultural based GDP.
- It is also a vital source of food to both urban and rural communities
- In sub-Sahara Africa, the livelihoods of more than 200ml people depend on crop cultivation and open grazing
- Over 36% of the livestock in Tanzania, are found in the Lake Victoria zone
- Agro-pastoralism in Tanzania is characterized by low production due to decreasing access to grazing land, and lack of quality fodder
- Magu district is dominated by agro-pastoral communities.
- About 90% of the population is engaged in crop cultivation and livestock keeping
- Information concerning the accessibility, conservation and production of fodder for the sustainability of agro-pastoral societies remains elusive.

Materials and Methods

- ✓ This study was conducted in Magu district
- ✓ By considering the land structure, the grazing areas were categorized into two sites
- ✓ The highland and lowland based on agro-ecological zones that communities use to obtain the fodder.
- ✓ Lowland are mainly used for grazing while highlands (Ngitiri) are used for cultivation and conservation of pasture

Results

- ✓ Lowland site had high species diversity and high relative abundance compared to the highland site
- ✓ No significant differences on the biomass between the highland and the lowland sites

No significant relationship between the species diversity and the biomass of the fodder species

Conclusion

- ✓ This study shows that, there is low relative abundance and diversity of grasses and herbaceous fodder that leads to low productivity of rangelands in Magu district.
- ✓ It also shows households' gender, land size, number of livestock, and physical capital have divergent influence on the accessibility of fodder during the dry and wet seasons. Household heads' education and income level have positive influence on households' willingness to participate in conservation of fodder sources.