Enhancing productivity and resilience of semi-arid rangelands of southwestern Zimbabwe: A case of adaptation in extensive livestock production in a communal area

Alois Sifelani Hlatshwayo

A thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy Majoring in Sustainable Agriculture

Department of Sustainable Food Systems and Development

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ABSTRACT

The main objective of this study was to enhance productivity and resilience of semi-arid communal rangelands through manual and livestock seed dispersions and fodder production adoption. Semi-arid communal rangelands support livestock production which is the flagship of food security and livelihoods in the areas. Three treatments; Seed + Ridges, Seed +Ridges + Brushwood, Seed + Brushwood and a Control were used to reseed a degraded semi-arid communal rangeland. Results showed that Treatment had a significant effect on reseeding. Grass seedling counts were significantly higher ($p<0.01$) at treatments Seed + Ridges and Seed + Ridges + Brushwood. Grass species diversity increased at treatment Seed + Ridges + Brushwood where frequencies were as follows: *Heteropogon contortus* 13.8%, *Schmidtia pappophoroides* 12.1%, *Urochloa mosambicensis* 11.5%, *Eragrostis trichophora* 9.8%, *Eragrostis rigidior* 6.9%, *Panicum maximum* 6.3% and *Eragrostis superba* 0.6%. Most observed grass species had good forage value. Treatment also influenced biomass production: Seed + Ridges + Brushwood 0.285^{a} t/ha, Seed + Brushwood 0.254^{ab} t/ha and Seed + Ridges 0.204^{b} t/ha and Control 0.079^{c} t/ha.

In the second experiment, cows were used to reseed a semi-arid communal rangeland. Four treatments and a Control were used. Treatment 1: Seven days after grass seeds started showing physiological maturity, 40 animals were grazed for 24 hours on diversified grass species, after 24 hours, the animals were taken away. On the following day ten animals were randomly selected and 20g of dung collected from each animal. Treatment 2: The process was repeated after fourteen days, Treatment 3: twenty-one days, Treatment 4: twenty-eight days and for the Control a soil sample was collected from a degraded area. The dung samples were dried in a sample room. Each dry dung sample was gently mashed. River sand was collected, and heated in a dehydrator for 48 hours at 80^{0}C to sterilise it. The sand was allowed to cool off, then put in labelled germination trays. Each mashed dung sample was spread in a labelled germination tray and watered. Results showed significantly higher seedling counts and species diversity in Treatments I and 2 than in Treatments 3 and 4. Seedling counts increased from day 7 to day 14 but decreased from day 21 to day 28. This seed dispersion method is effective however, time factor is very important for its success. Observed grass species had good forage value.

An investigation on fodder production adoption in semi-arid communal areas was conducted through a structured questionnaire administered to 125 farmers. Results showed a proportion of 61.4% of respondents used fodder, 1.3% used commercial feeds and 37.7% used both.

Respondents preserved their fodder as indicated by 86.7% who prepared hay, while 13,3% prepared silage. Livestock species supplemented during the dry season included cattle, goats and donkeys. Fodder production adoption had an effect on livestock mortalities; 97.3% of respondents said mortalities decreased and 2.7% saw an increase

A survey to investigate allocation of financial resources from livestock sales to family needs was conducted through a structured questionnaire administered to 125 randomly selected farmers. Survey results showed 95% of respondents sold livestock to private buyers and 5% to abattoirs. A proportion of 52% of respondents conducted livestock sales every 3 – 6 months and 35% 6 – 12 months. Usually sold animals included: cattle 31.0%, goats 27.6%, Chickens 27.6%, sheep 9.2% and donkeys 4.6%. Money from livestock sales was allocated as follows; food 33.3%, medication 33.3%, school fees 27.3% and restocking 6.1%. The results indicate that semi-arid communal farmers sell their livestock, and that their animals are a store of wealth used to enhance food security and livelihoods.

In conclusion, results of the two experiments show effectiveness of restoring degraded environments through manual/mechanical and livestock seed dispersions. Grass species diversity and forage value can be increased through manual and livestock seed dispersions. By manually dispersing seeds, results show that biomass production can be increased on low producing semi-arid communal rangelands, since production trebled at Treatment; Seeds + Ridges + Brushwood and doubled at Seeds + Ridges. The methods promise to be useful tools for restoring semi-arid communal rangelands, which have been constrained by degradation for many years, thereby raising productivity and resilience, which in the long term will boost livestock productivity in the areas. Further to being effective, the reseeding methods, are environmentally friendly, cheap and easy to implement.

Results of the fodder production adoption survey showed high adoption among farmers which promises to reduce over dependency on rangelands for livestock feed and enhance natural regeneration in the long term. Fodder production adoption promises to be a useful tool for permanently solving feed shortages in semi-arid communal areas.

Results of the financial resource allocation survey, showed that farmers sell livestock periodically and use the money to buy food, medication, pay school fees and restock to make livestock production sustainable. All these, significantly confirm that semi-arid communal rangelands play a pivotal role in food security and livelihoods.

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Glossary

Annual species	Plants that complete their life cycle in one growing season
Anthropogenic activities	Activities caused by humans
Biomass	Amount/weight of living matter in a certain area/habitat
Exclosure	An area that is surrounded by a barrier
Fodder	Food, especially hay/straw for cattle and other livestock
Forage	Food such as grass or hay for horses and cattle
Forbs	Herbaceous flowering plants other than grass
Graminoid	Plant related to grass
Hay	Dried grass or other foliage used as animal feed
Invasive species	A species foreign to an ecosystem which causes harm to it
Mixed veld	An area with mixed sweet veld and sour veld components
Perennial species	A plant that lives for more than two years
Poacea	Plants commonly known as grasses
Reseed	Sow an area with seed especially grass seed
Semi-arid	Dry, with little rain
Silage	Type of fodder compacted in an airtight environment (silo)
Soil seed bank	Natural storage of dormant seed in the soil
Sour veld	Veld characterized by long coarse grass
Sweet veld	Veld with palatable grazing, mainly annuals

Acronyms

CGIAR	Consultative Group for International Agricultural Research
CIAT	International Centre for Tropical Agriculture
CP	Crude protein
DCP	Dicalcium phosphate
DM	Dry matter
DWR	Dry weight rank
FAO	Food and Agriculture Organisation
FGD	Focal Group Discussion
GLM	General Linear Model
IPCC	Intergovernmental Panel on Climate Change
K	Potassium
LAB	Lactic acid bacteria
LSCF	Large Scale Commercial Farmer
LSD	Linear Significant Difference
S	Sulphur
SB	Seeds and brushwood
SBR	Seeds, Ridges and Brushwood
SPSS	Statistical Package for Social Scientists
SR	Seeds and ridges
SRLCA	Special Report on Crop and Livestock Assessment
VFA	Volatile Fatty Acids
UNFCCC	United Nations Framework Convention on Climate Change

1 CHAPTER ONE

1.1 Background

Semi-arid rangelands occupy sixty-five percent of Zimbabwe's total area and, are major players in the country's livestock production system, contributing 86% of the national herd (Mashoko et al., 2007; Tavirimirwa et al., 2013) which includes 5 598 982 cattle, 3 974 707 goats and 697 910 sheep (SRCLA, 2020). They provide cheap livestock feed, (Grissom and Steffens, 2013; Mudzengi et al., 2017) and are easily accessible (Chaminuka et al., 2014) which make them an important matrix in the livestock production value chain (Diogo et al., 2020). Their major function is providing livestock fodder (Kgosikoma et al., 2015) which includes grasses, browse and forbs (Penderis and Kirkman, 2014; Mariotti et al., 2020; Vundla et al., 2020). Livestock provide an assortment of goods and services such as savings and capitalization (Gamoun et al., 2015; Diogo et al., 2020) food security and livelihoods (FAO, 1992; Thornton, 2010), as dry land crop production usually fails (Phiri et al., 2019). Animals tolerate droughts, which makes them more suited for semi-arid production (Thornton and Gerber, 2010; Thornton et al., 2009). Livestock production gives assurance against natural shocks such as droughts, food insecurity and poor livelihoods, to many semi-arid communal farmers (IPCC, 2007; Norton et al., 2013).

1.2 Management, ownership and utilization of semi-arid rangelands

Semi-arid rangelands play a very important role in the livestock production sector. However, the conspicuous absence of management plans or strategies for the rangelands is threatening their sustainability (Holechek et al., 2011; Gamoun et al., 2014; Hunt et al., 2014). A matter of concern affecting communal smallholder farmers is the issue of land ownership, rangelands are communally owned, utilized and governed by Rural District Councils (RDC), (Cotula et al., 2004). Consequently, due to the unclear land ownership policy in communal areas, rangeland management is not impressive thus far. No one is answerable for the unsustainable activities that damage the natural resource whose contribution to livelihoods and food security is invaluable (Moritz et al., 2013). In addition to challenges affecting livestock production in communal areas, is over utilization which is driven by anthropogenic activities (Abate et al., 2012; Rutherford and Powrie, 2013; Beyene, 2016), while climate change is also complicating the matter (Galvin et al., 2004; UNFCCC, 2008). The two factors cause low rangeland production (Kassahun et al., 2008b), a problem that has been affecting semi-arid rangelands over the years (Abate et al., 2010). Low biomass production on rangelands has a negative implication on livestock production, as it is the precursor of feed shortages more so in semi-arid areas, considering the frequent incidents of droughts there (Breckle et al., 2001; Gemedo et al., 2006; Cingolani et al., 2005). In the past years, many livestock have been lost through death by starvation especially in worst drought years (Oba and Kotile, 2001) and more will still be lost if a long-term solution is not put in place. While loss of vigour and species biodiversity on the rangelands are apparent, fragmentation of rangelands is also a worrisome development (Behnke, 2008) driven by high demand for agriculture land (Senda et al., 2020; Greiner et al., 2013; Hobbs et al., 2008). This is happening, despite the common knowledge that livestock production is a better agricultural option than dry land crop farming. As a result, a lot of grazing pressure is exerted on the bits and pieces of the remaining grazing spaces (Ibanez et al., 2007; Hlatshwayo, 2017) creating unnecessary competition for a diminishing feed resource base among animals. On the ecosystem, it causes changes in species diversity and standing biomass (Dembele et al., 2006; Deng et al., 2013). Poor grass species take over, and replace extinct grass species of good forage value (Patton et al., 2007; Sasaki et al., 2012). Consequently, feed shortages become common especially during the dry season when the rangelands offer feed that is low in both quality and quantity (Liu et al., 2009; Tarhouni et al., 2007) and the situation gets extreme during drought years (Vetter et al, 2020; Wigley-Coetsee and Staver, 2020).

1.3 Factors affecting condition, production and sustainability of semi-arid rangelands

Semi-arid rangelands (SAR) all over the world, and more so in Zimbabwe, support extensive livestock production, and will continue to do so for a long time to come (Hoffman et al., 2018; O' Connor, 2015). However, they suffer from a disequilibrium between utilization and regeneration of plant species ((Wigley-Coetsee and Staver, 2020; Gillson et al., 2019). This is mainly driven by human factors (Deng et al., 2013; Bo et al., 2013; Ibanez et al., 2007), though forces of nature also contribute through droughts and climate change which add their foot prints (Rhode and Hoffman, 2012; IPCC, 2013; Vetter et al., 2020). Currently the semi-arid rangelands are threatened by steadily progressing degradation (Hoffman et al., 2018), due to many years of mismanagement and abuse (Bai and Dent, 2009; Higginbottom and Symeonakis, 2014). An undesirable change in vegetation species is noticeable (Rutherford and Powrie, 2010). This will worsen feed shortages, which have been threatening livestock production annually particularly in communal areas (Myers et al., 2000; Eldridge et al., 2016). Since livestock production drives rural micro-economies (Gamoun et al., 2015), rangelands need to continue producing feed without disturbances.

Grazing on communal rangelands is characterized by high population pressure and heavy utilization (Ibanez et al., 2007; Louhaichi and Tastad, 2010), and this does not auger well for rangeland sustainability (Tarhouni et al., 2007). Most livestock in communal areas are not penned overnight, causing grass species to be grazed continuously without rest (Rutherford and Powrie, 2013; Villagra et al., 2009) resulting in degradation (Liu et al., 2009; Bo et al., 2013). Rangeland degradation is like a plague to livestock production, as it induces feed shortages (Chanda et al., 2003; Hickman et al., 2004). Feed shortages always haunt semi-arid communal farmers who are vulnerable and resource constrained (Gamoun et al., 2014; FAO, 1992). There is no doubt that rangelands provide cheap feed, which provides nutrients and minerals to livestock (Van Der Westhuizen et al., 2001; Mugasi et al., 2000), and livestock owned by communal farmers are included. Therefore, the rangelands' sustainability is paramount (Yates et al., 2000). This enables the rangelands to continue to support livestock production (Abate et al., 2012; Anderson et al., 2014) and in turn rangelands prop up livelihoods and food security (Thornton et al., 2010).

1.4 Healing the "sick" semi-arid rangelands

Following several years of unsustainable and unmanageable utilization methods, semi-arid communal rangelands, are now "sick" (Peters et al., 2013; Reynolds, 2013) and unproductive (Archer and Smeins, 1991; Tarhouni et al., 2007). Severe changes have occurred on the rangelands, especially in the soil chemical composition and above ground biomass (Kimiti et al., 2017). Scientific evidence proves that animals alter vegetation species through grazing and browsing (Bo et al., 2013; Louhaichi and Tastad, 2010) resulting in low biomass production and degradation in extreme cases. Semi-arid communal rangelands support livestock production which significantly influences food security and livelihoods (Mussa et al., 2016). In respect of this reality, the rangelands should remain productive and sustainable. In return the rangelands can continue to provide cheap fodder to livestock, while humans can get products, by-products and services to sustain their livelihoods. It is apparent that semi-arid communal rangelands are severely degraded and badly need rejuvenation (Abdelsalam et al., 2017) to boost above ground biomass and vegetation species diversity (Karubian and Duraes, 2009). Following this, the rangelands will continue to function properly without interference from external factors, whether natural or human induced. Rangeland restoration can be undertaken in two ways: (i) Manual seed dispersion and (ii) Animal-mediated seed dispersion (Williams and Shepherd, 1991; Nordborg and Roos, 2016). The two methods of rangeland rejuvenation used concurrently and satisfactorily, can complement each other to raise productivity of the rangelands, restore ecosystems and habitats and avail more fodder for livestock.

1.5 Mechanical seed dispersion

Over the years, rangeland regeneration has been occurring naturally, and agents such as wind, water and animals influenced dispersion of seed for perpetuation and persistence of vegetation species significantly (Saatkamp et al., 2014; Karubian and Duraes, 2009). Through the natural mechanism, soil-seed banks, the major drivers of regeneration are replenished effectively (Gomaa, 2012; Liu et al., 2016). However, human population is increasing, and so is demand for livestock products, by-products and services, while nature is failing to produce enough plant materials to match the demand for fodder by the increasing animals (Rohde et al., 2006; Puttick et al., 2014). The disparity induces perennial feed shortages, which threaten viability of livestock production in the semi-arid regions seriously (Izzauralde et al., 2011). Therefore, man must intervene on nature's behalf by manually recharging soil-seed banks, which are severely depleted due to factors such as recurrent droughts, over stocking and overgrazing (Kimiti et al., 2017). Manual seed dispersion has several merits that benefit both the rangelands and livestock in the long run (Liu et al., 2016). Some of the benefits include introduction of good forage-value species, guaranteed species diversity, increased biomass production and cover which are easy and cheap to implement (Scholz, 1995). The exercise only requires seed of different grass species to be picked during the growing season and stored for use at the right time. Above all, restoration success is guaranteed as long there is adequate rainfall during a season the seed is broadcasted (Saunders et al., 1993). However, one limitation is sometimes seed is harvested a little too soon before physiological maturity and cause poor germination.

1.6 Livestock mediated seed-dispersion

Animals dependent very much on plants on rangelands for all their energy requirements (Hempson et al., 2015). Through adaptation to their environments, animals influence micro-ecosystems and enable plant succession, a mechanism that is responsible for promoting grass communities' diversity (Young et al., 2020). Due to the grazers' influence on the structure and function of ecosystems where they feed, animals can be used to rejuvenate the same ecosystems (Nordborg and Roos, 2016). Livestock can participate in the succession and grass communities' diversity by dispersing seed passively on the rangelands via dung (Olff and Ritchie, 1998; Venter et al., 2015). The mutual relationship between rangelands and grazers plays a major role in maintaining ecosystem balance and perpetuation of herbaceous species (O'Connor and Pickett, 1992). In cases where desirable plant species have been depleted rendering rangelands degraded and unproductive, livestock can be used to restore such areas effectively (Frost and Hunter, 2007; Cromsigt et al., 2017; Hopcraft et al., 2010). The objective is to increase rangeland productivity and build resilience through different restoration methods. The rangelands will in turn, continue to feed livestock whose importance to livelihoods and food security in communal areas needs no emphasis.

1.7 Dealing decisively with degradation on semi-arid rangelands (SAR)

There is no doubt that semi-arid rangelands, have long been constrained by a number of challenges, which hinder productivity (Kgosikoma et al., 2015; Hoffman et al., 2018). Major drivers of most challenges are natural factors such as weather (Malherbe et al., 2020) and human factors (Bonnet et al., 2010). Combined, the factors worsen feed shortages, threatening viability of extensive livestock production from the rangelands (Thornton et al., 2009; Thornton and Gerber, 2010). Low precipitation and heavy utilization in semi-arid areas cause a disconnection between species composition and rangeland productivity thus inducing less fodder for livestock. Due to the significance of livestock production to livelihoods and food security in semi-arid areas, much effort is needed to make rangeland utilization sustainable.

However, on their own semi-arid rangelands, cannot satisfy grazers' demand for fodder as they receive low and highly variable rainfall (Ebei et al., 2007), in addition to being over stocked and over grazed (du Toit et al., 2018; Vetter et al., 2020) which culminate into annual feed shortages (Day et al., 2003). A long-term solution to feed shortages is required (Hargreaves et al., 2004) to avert future disasters. Many livestock died in semi-arid communal areas in the past, and more will continue to die, if a permanent solution is not found (Thornton et al., 2015). The most appropriate intervention is fodder production and preservation to create fodder banks (Ansar et al., 2010; Al-Karaki and Al-Hashimi, 2011), to enhance dry season supplementation. Fodder gardens or planted pastures can augment the little fodder produced on rangelands naturally. The advantage of fodder is that some of it, can be grown on dry land production (Mhere et al., 2002; Mwembe and Tavirimirwa, 2020) and under irrigation (Cuddeford, 1989; Al-Hashmi, 2008), and both cases can produce good results.

Forage production has several benefits including high yields, good nutritive value and high palatability making them readily acceptable to livestock (Capstaff and Miller, 2018). In addition to good nutritive value fodder can be used as a tool for building rangeland resilience (CIAT and CGIAR, 2015). Fodder can reduce grazing pressure on rangelands and enhance significant recovery after grazing (Derner et al., 2017). Fodder can also lessen communal farmers' over reliance on rangelands for livestock feed, which renders semi-arid rangelands unproductive and in need of correctional interventions (Sala and Paruelo, 1997; Brkljacic et al, 2011). Producing fodder is a cheaper way for communal farmers to avail more feed to livestock (CIAT and CGIAR, 2015) and permanently deal with perennial feed shortages that constrain livestock production in the regions. In the long-term, rangelands will regenerate naturally (Saunders et al., 1993; Scholz, 1995; Karubian and Duraes, 2009) because they will no longer be under heavy grazing pressure. Symbiotic co-existence must be nurtured between man and the God-given natural resource known as rangelands (Jones, 2017; Jones et al., 2017). Man has an obligation to look after the environment (rangelands) well, in turn it will satisfy his social, ecological and economic needs.

1.8 Significance of the study

This study reacts to results of research work for a dissertation conducted for a Master Degree entitled, "The effect of open (uncontrolled) grazing on semi-arid communal rangelands of southwestern Zimbabwe". It was conducted in Pelele village, Gwanda District, Matabeleland South Province. The village has three lines; Likakeng, Mbirwane and Nyikanyoro, with a population of 160 households distributed among the three lines. Communal farmers in this area, practice a crop-livestock system of agriculture, but, since they are living in a semi-arid region, livestock production is the better agricultural option. Livestock in the area comprise 500 cattle, 300 donkeys, 600 goats and 250 sheep, grazed on a communal rangeland. Grazing space is declining steadily due to fragmentation because of high demand for cropping land (Senda et al., 2020). Results of the study showed heavy grazing, and a major shift in species composition on the rangeland (*Aristida barbicollis* was dominant), low rangeland productivity (0.117t/ha) and subsequent rangeland degradation (Eleven grass species identified, and only four were palatable) (Hlatshwayo, 2017). Due to the significance of livestock production and its importance to livelihoods and food security, good rangeland condition and productivity are necessary for the agricultural activity to remain sustainable.

The study was conducted on rangeland grazed communally, where 169 ha were fenced off to exclude grazing by livestock. However, farmers sometimes sneak their animals into the site at night to eat new good grass in the exclosure. This kind of behaviour was threatening effectiveness of the project, but community leaders conducted awareness campaigns to deter culprits and allow the rangeland to recover.

In addition to the two methods of seed dispersion, the study used biophysical assessment to take an inventory of species growing on the site, as well and the Free Listing Method (FLM) to establish the species that were growing there some years back. The objective was to assess changes that took place in the species diversity due to several years of unsustainable rangeland utilization methods. Species composition has a direct influence on rangeland productivity and nutritive value of species.

The rangelands fall in a region with low and highly variable rainfall hence they are commonly referred to as sweet veld. Grass species in the area are nutritious throughout the year, resulting in over grazing due to over stocking which drives rangeland degradation. However, degraded land is not productive, therefore the anomaly needs reversed, so that food security and livelihoods dependent on livestock production can remain sustainable.

2 CHAPTER TWO REVIEW OF LITERATURE

2.1 Importance of rangelands to livestock in Africa

Over fifty percent of Africa practices one form or another of pastoralism as a source of livelihood (Abebe et al., 2012). Rangelands are the basis of pastoral life, they provide grazing to a variety of livestock species such as camels and goats in drier regions, and cattle, sheep and goats in higher rainfall areas (Behnke et al., 2011; Davies et al., 2016). The different species of livestock guarantee assurance on food security (Tessema et al>, 2014) and a source of livelihood for the over 236 million pastoralists in the different regions of Africa (Schmidt and Pearson, 2016). Pastoral livelihood is practiced in different forms such as; (i) Nomadic pastoralism where livestock owners move along with their herds in search of grazing, (ii) Seasonal pastoralism in which case herders migrate searching for new grazing and (iii) Transhumance pastoral life which is more or less like herders (Grebremeskel et al., 2016). However, there is another dimension to the pastoral practice, farmers have assumed a sedentary lifestyle and practice a crop-livestock system of agriculture. This enables them to spread risk against effects of natural calamities like diseases, floods and droughts which sometimes disrupt agricultural activities. Crops and livestock complement each other in providing food security and livelihoods to smallholder farmers who practice them.

The age-old pastoral practice has been maintained and passed on from generation to generation through indigenous knowledge systems (IKS) (Oba, 2012). Rangelands have supported pastoral livelihoods over hundreds of years, however, their future faces uncertainty as there are many challenges haunting them (Senda et al., 2020). The most notable challenges are rangeland fragmentation and loss of grazing (Clavijo et al., 2005; Desta and Coppock, 2004; Beyene, 2016), impacts of climate change and variability (Galvin et al., 2004; FAO, 2012) and conflicts over land use and rights (Ambaye, 2012; Benjaminsen et al., 2009; Fernandez-Giminez, 2002; Kuusaana and Bukari, 2015).

Despite the odds, rangelands continue to support livelihoods and food security as pastoral life is all what pastoralists know, and they are expected to pass on the legacy to generations of future pastoralists. Going forward, semi-arid rangelands must be conserved and nurtured to ensure they do not become derelict and fail to feed animals.

2.2 The importance of rangelands to livestock in semi-arid areas of Zimbabwe

Rangelands can be defined as lands on which the native vegetation is predominantly grasses, grass-like plants, forbs or shrubs suitable for grazing or browsing whether in their climax or natural potential communities (Abate et al., 2010). Globally, fifty percent of the earth's surface is made up of rangelands (Menke and Bradford, 1992) and in Zimbabwe, sixty-five percent of the country comprises of rangelands, situated in agro-ecological regions IV and V (Vincent and Thomas, 1960; Mugandani et al., 2012). The regions receive low and highly variable rainfall hence they are commonly referred to as the semi-arid regions (Homann et al., 2007; Havstad et al., 2007).

Dry land cropping in semi-arid regions is always unsustainable due to recurrent droughts, low and patchy rainfall (Phiri et al., 2019) resulting in annual crop failures, which induce food insecurity (Murungweni et al., 2016). However, livestock production stands out as a better agricultural option (FAO, 1992) due to its tolerance to long dry periods which are very common in semi-arid regions (Thornton et al., 2015). As a result, livestock production is mainly associated with societal needs such as food security and livelihoods (Anderson et al., 2014; Beyene, 2016). Communal farmers in semi-arid regions have taken to livestock production in their numbers fully, to keep their micro-economies running (Abate et al., 2010; Abate et al., 2012). Livestock production, is supported by rangelands which are sources of cheap feed all year round (Gamoun et al., 2014; Chaminuka et al., 2014; Derner et al., 2017). Farmers in semi-arid regions keep livestock including; cattle, goats, sheep and donkeys (SRCLA, 2020) from which they derive many products, by-products and services to sustain their livelihoods. Benefits from livestock come in the form of meat, milk, money, manure and animal draft-power which translate to food security in households (Steinfeld et al., 2006). Rangelands make it possible for farmers to derive the benefits from livestock through the animals' ability to convert grasses and browse into tangible materials that people can use (Day et al., 1997; Day and Phelp, 1997). A livestock farmer can be likened to an entrepreneur who owns factories, the only difference being that in this scenario the factories are livestock which require raw materials in the form of plant materials (grasses, forbs and browse) (Ebei et al., 2007). Animals convert the materials, into food (milk, meat) and money which the farmers can readily use to satisfy family needs. Grasses, forbs and browse grow abundantly on rangelands, and this demonstrates how important rangelands in semi-arid regions of southwestern Zimbabwe are to people's livelihoods.

Although the major function of semi-arid rangelands is to supply cheap grazing (Anderson et al., 2014) and browse (Mukungurutse, 2002; Sebata and Ndlovu, 2010; Sebata and Ndlovu, 2011; Mudzengi et al., 2017) to animals, there are other natural resources generally referred to as non-timber forest produce (NTFPs) that are important in the day to day lives of rural folks, also derived from the rangelands (Mahonya et al., 2019). The items play an important role, in rural people's micro-economies, livelihoods and food security (Angelsen et al., 2014). NTFPs maintain micro rural economies and boost food security in several households (Awono et al., 2010). They include an assortment of items such as fuel/firewood, thatch grass, wild fruits, wild vegetables, medicines, bush meat, mopani worms and rope fiber (Abtew et al., 2012; Adam et al., 2013; de Sousa et al., 2018). Rural people, regard semi-arid rangelands, as God-given natural resources, easy to access and heavily depend upon (Chaminuka et al., 2014) for food and livelihoods (Mudzengi et al., 2017). In addition to provision of food, NTFPs are sources of income for rural folks whose majority is financially constrained (De Sousa et al., 2018; Adam et al., 2013; Abtew et al., 2012). Therefore, it can safely be concluded, that rangelands and their NTFPs effectively alleviate poverty and food insecurity of rural folks in semi-arid communal areas and will continue to do so for a long time to come.

2.3 The role of rangelands to livestock production in semi-arid communal communities

Zimbabwe's agro-driven economy is greatly influenced by the country's five agro-ecological zones (Mugandani et al., 2012), which determine the location of each agricultural activity. The country was partitioned into the five natural regions to ensure efficient land utilization to sustain food security (DMS, 1981). The country has two major agricultural activities; crop farming and livestock production both practiced in high and low rainfall areas respectively (Nyakanda, 2005). In the semi-arid regions, rain fed cropping does not always produce desired results (Hussein, 1987) hence extensive livestock production from the rangelands, is the better agricultural option (Steinfeld et al., 2006). Livestock produce various products and services essential in people's day to day lives (Anderson et al., 2014). All this is made possible by rangelands which form the backbone of livestock production (Undersander et al., 2002).

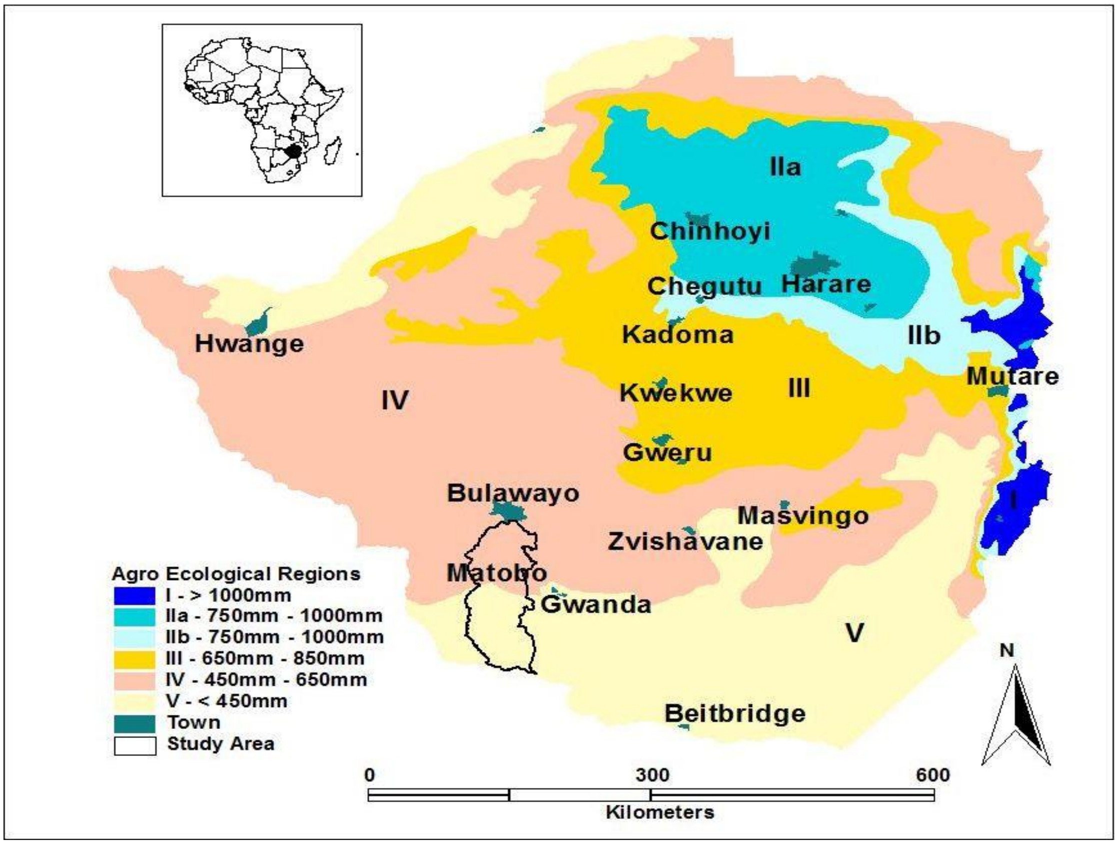


Figure 2.1: The five Agro-ecological zones of Zimbabwe

Table 2.1: Five Natural Regions and farming systems of Zimbabwe

Natural region	Area (km2)	Annual rainfall (mm)	Rainfall Intensity	Farming System
I	5835	1000 - 900	High rainfall	Specialized
II	72 745	900 - 750	Moderately high	Intensive
III	67 690	750 - 650	Moderate	Semi-intensive
IV	128 370	650 - 450	Fairly low	Semi-extensive
V	112 810	<450	Low, erratic	Extensive

(Source: Day et al, 2003).

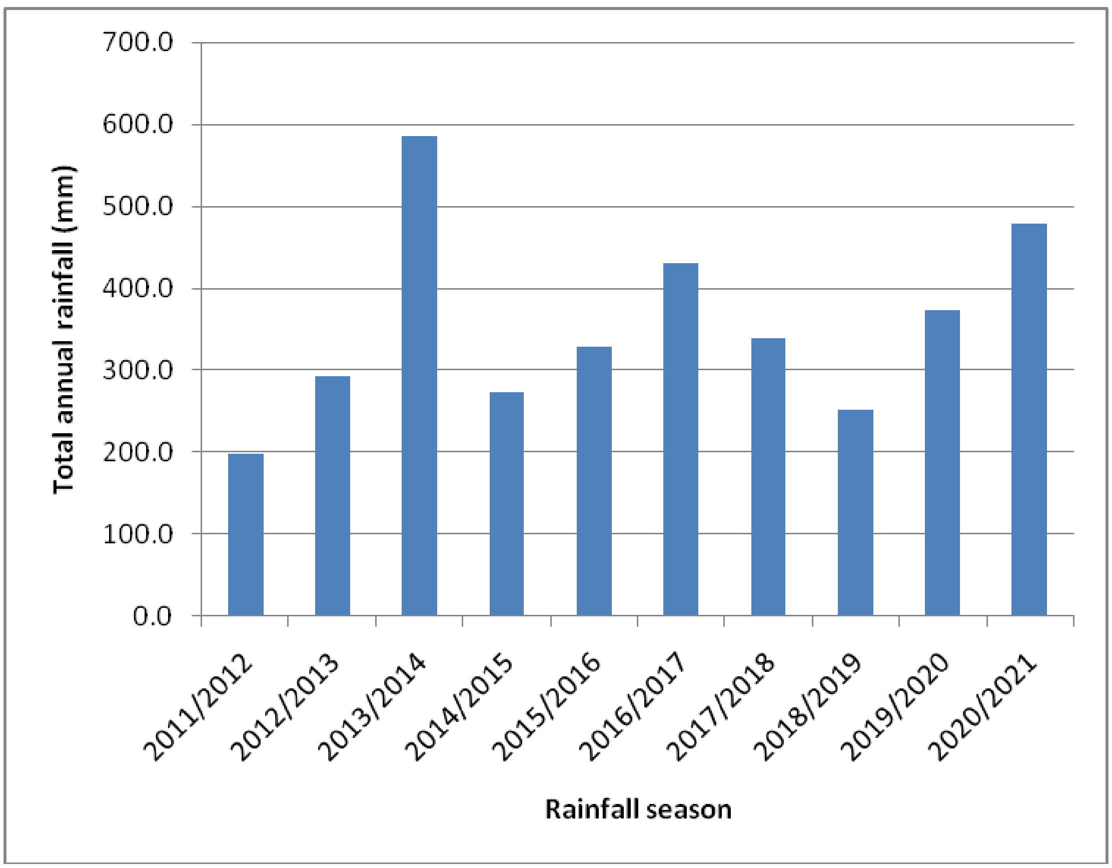


Figure 2.2: Annual rainfall for Pelele, Gwanda District

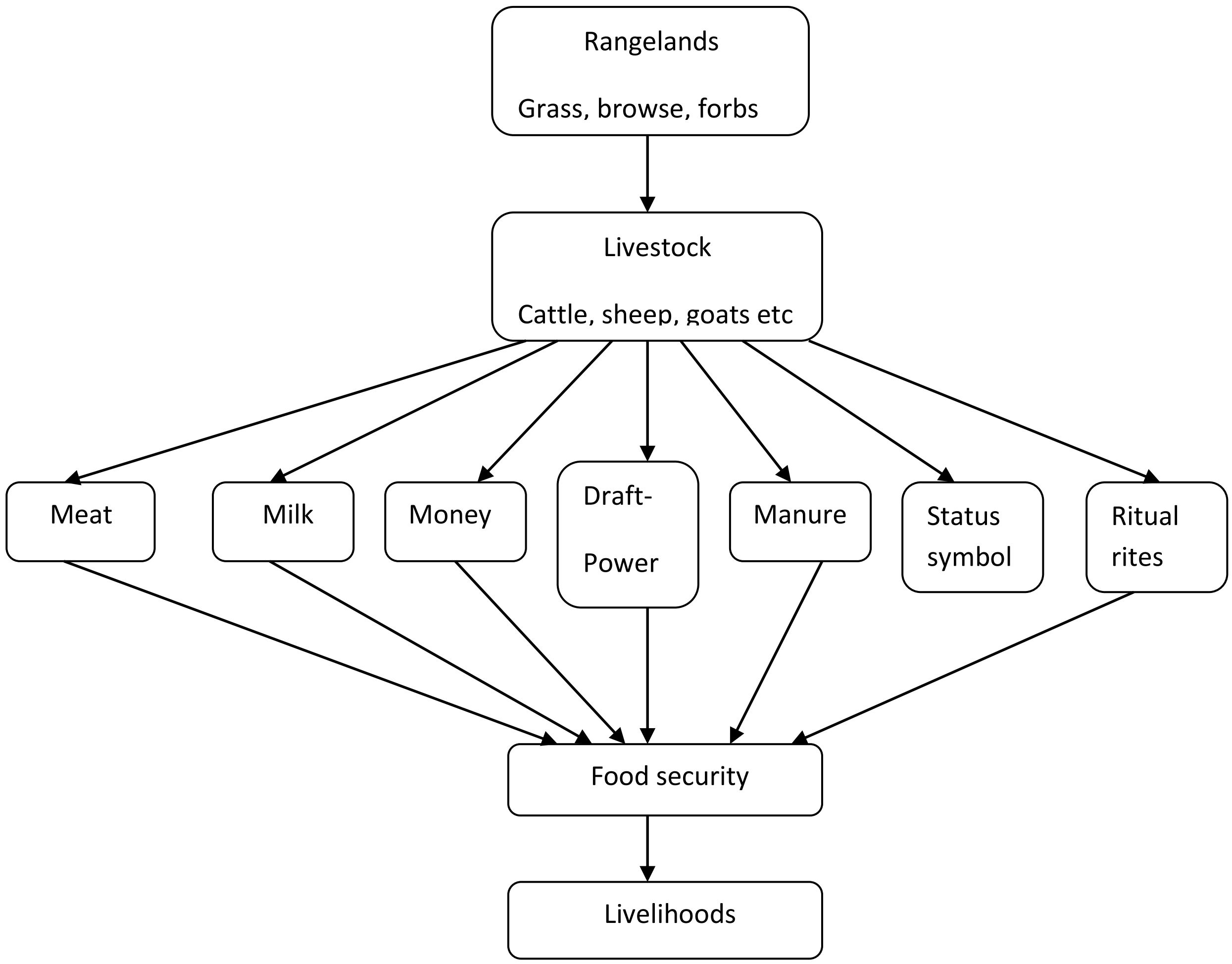


Figure 2.3: The significance of rangelands on food security and livelihoods in semi-arid communal areas

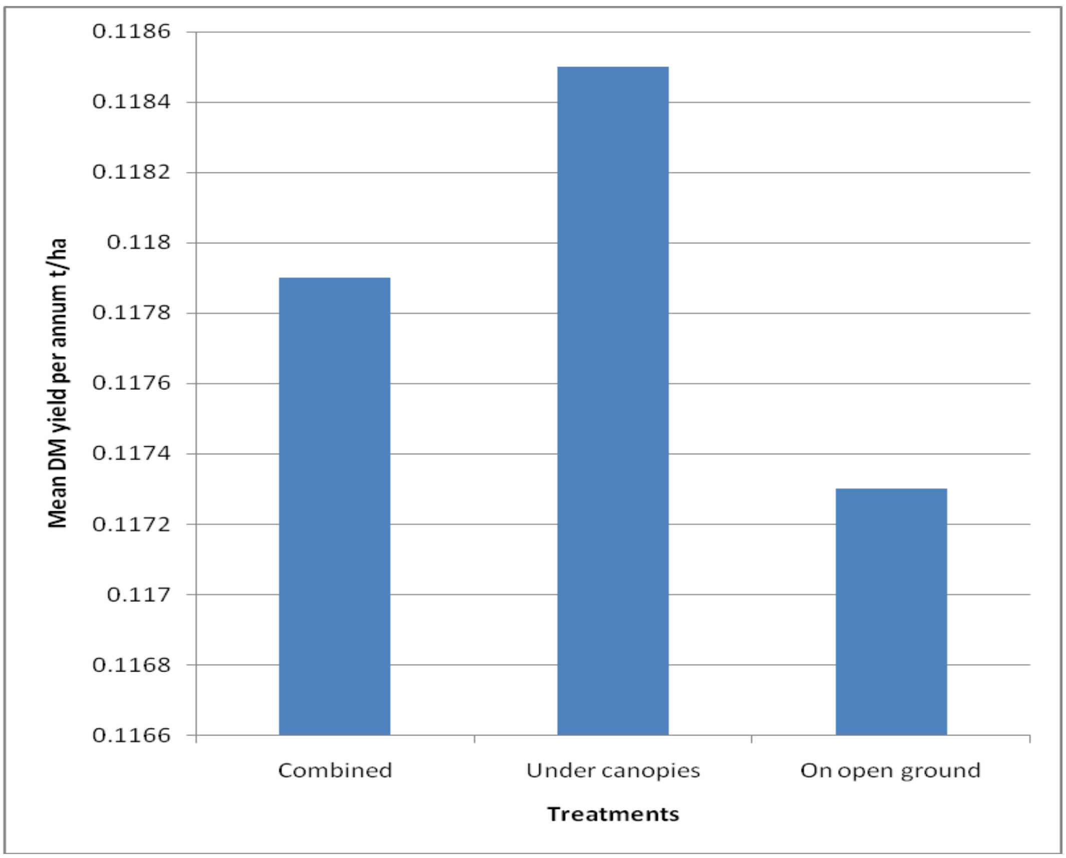
Semi-arid rangelands' significant role in sustaining livelihoods needs not be over emphasized (Havstad, 2007). They are the important cog that keeps food security and livelihoods in semi-arid areas turning (Twilley and Manaugh, 2013). Sustainability, perpetuation and persistence of vegetation species on the rangelands must be nurtured to benefit of livestock production (Willms et al., 1990). The current generation of communal farming communities in semi-arid areas has an obligation to pass on a legacy, to the future generation of rangeland users (Chanda et al., 2003; Hlatshwayo, 2017). By failing to act responsibly, the current generation risks being blamed by future generations for running down the legacy which is expected to benefit future generations.

2.4 Productivity and sustainability of semi-arid communal rangelands

In agriculture production, rainfall is a very important variable whose influence on plant productivity potential's success or failure is significant (Doorenbos and Kassam, 1979; Mason and Jury, 1997). Because they are situated in Natural Regions IV and V (Vincent and Thomas, 1960; Mugandani et al., 2012) semi-arid rangelands receive very low and highly variable rainfall, negatively affecting biomass production and rangeland sustainability (Hein, 2006). Semi-arid communal rangelands have been known for producing low biomass for a long time, because of a number of factors including low rainfall, frequent droughts (Darkho, 1990), high population pressure (Bo et al., 2013; Deng et al., 2013) and unsustainable utilization methods (Day et al., 1997). The problem is exacerbated by climate change and variability (Izzauralde et al., 2011), which pile negative pressure on productivity, vigor and persistence of some plant species with good forage value (Abate et al., 2012).

Due to low biomass production, feed shortages in semi-arid communal areas are a perennial constraint affecting livestock production (Thornton et al., 2015; Kgosikoma et al., 2015). Most communal farmers lack financial resources to enable them to buy commercial feedstuffs for dry season supplementation, hence they depend heavily on rangelands (Chaminuka et al., 2014; Mudzengi et al., 2017). Many of them suffered huge livestock losses during two severe droughts of the early 1980s and 1990s (Abebe et al., 2012), compromising livelihoods (Day et al., 2003). They experienced food insecurity as their sole reliable source of livelihood was snatched away from their grasp by forces of nature (Hargreaves et al., 2003; Ebei et al., 2007). Feed deficits will continue to haunt semi-arid communal farmers, so they must devise an adaptation strategy (Roux and Foxcroft, 2011). Utilization of semi-arid rangelands must be sustainable first (Anderson and Hoffman, 2007) so that livestock can continue to get fodder, while farmers get benefits from the livestock (Havstad, 2007).

However, the situation on the ground paints a gloomy picture, communal rangeland utilization is complicated because of factors including; continuous decline in grazing space due to rangeland fragmentation (Clavijo et al., 2005; Desta and Coppock, 2004), high grazing intensity (Deng et al., 2013) and climate change and variability (Thornton et al., 2015; Allreda et al., 2014). Lack of statutes and regulations to govern rangeland utilization in semi-arid communal areas is leaving a disastrous footprint on rangeland sustainability. Should the situation be left to continue as it is, livestock production will face annual feed shortages forever, because the natural stability of rangelands is declining at an alarming rate.



Source: Hlatshwayo, 2017

Figure 2.4: Biomass production on semi-arid communal rangelands

2.5 Problems associated with utilization of semi-arid communal rangelands

Grazing on semi-arid rangelands is nutritious all year round, because the rangelands are situated in Agro-ecological Regions IV and V commonly referred to as sweet veld. Zimbabwe has three major veld types; sweet, mixed and sour (Mugandani et al., 2012). Sweet veld occupies sixty-five percent of the total area of the country justifying why it is renowned for extensive livestock production (Mugandani et al., 2012; Abate et al., 2012; Abebe et al., 2012). Despite the importance of semi-arid rangelands in livestock production, constraints are created by how they are utilized. The problems impede the full potential of livestock production in semi-arid communal areas which will be discussed in the paragraphs below.

2.6 Property rights in semi-arid communal areas

Semi-arid communal farmers in Gwanda District, or elsewhere in the country do not own land they utilize. It is communally owned instead and this applies even to rangelands in other Agro-ecological regions such as I, II and III where livestock production is also practiced. Communal land is state land that is administered by local authorities especially Rural District Councils (Mbiba, 2001; Mkodzongi and Lawrence, 2019). Lack of clarity and uncertainty over land ownership in communal areas, creates a disconnection between utilization and conservation of the natural resources. Despite common knowledge that they contribute significantly to people's livelihoods, no one feels obliged to conserve rangelands. This, together with other factors, whether biotic or abiotic compromise the condition of semi-arid communal rangelands, rendering them incapacitated to produce enough grazing for a season. There is wanton destruction and abuse of rangelands with activities such as deforestation, over stocking and over grazing which result in degradation being apparent.

2.7 Management of semi-arid communal rangelands

Semi-arid rangelands are famous for extensive livestock production, an agricultural activity credited for supporting livelihoods of many rural folks, whose hope for food security was dampened by perpetual annual crop failures (Murungweni et al., 2016). However, sustainability of the rangelands is a thorny issue stifling livestock production, because of its complicated nature (Anderson et al., 2014). There are no grazing management systems on semi-arid communal rangelands, which leaves the animals to free-range (Soder et al., 2007). They forage for fodder daily, everywhere and anywhere without restriction, rest or rotation (Barnes and Hild, 2013; Norton et al., 2013). Worse still, they are not penned overnight, a practice straining the rangelands' productive potential. The practice looks quite harmless and beneficial to both farmer and animal at face value since it does not involve herding of livestock, which cuts down on herding costs (Anderson, 2007). However, it has its own short coming, it does not encourage recovery of herbaceous plants after grazing (Fuhlendorf et al., 2001). This way of rangeland utilization is counterproductive to the perpetuation and persistence of perennial grass species with good forage value. Perennials are often grazed to extinction due to lack of chance to rejuvenate and manufacture their own food through the photosynthesis process. When good perennial species die, their place is subsequently taken over by annual species with an inferior grazing value. Animals practice selective grazing during feeding, through this feeding behavior they choose and pick what they would like to eat and leave what they don't like to eat (Deng et al., 2013). By and large heavily utilized grass species, lose diversity and vigor, good species are usually hard hit. In the end where there used to be perennial grass species, annual grass species which neither produce high biomass nor support livestock production take over the spaces.

In addition to biodiversity loss on poorly managed rangelands (Senda et al., 2020) there is steady decline in grazing space due to rangeland fragmentation, driven by rising demand for cropping land (Abebe et al., 2012; Greiner et al., 2013; Hlatshwayo, 2017). Lack of grazing management systems and by-laws to govern utilization of semi-arid communal rangelands, drive users to have differing views and aspirations regarding how the rangelands should be utilized or benefited from. Not all farmers own equal numbers of livestock; some have more while others own less or none at all. Such discrepancies compromise among farmers the spirit of conserving and sustaining the rangelands ending up over utilising them (Elloumi et al., 2001). Judging by the importance of livestock production on food security and livelihoods in semi-arid communal areas, it is incumbent upon development agents in both public and private extension services to direct their intervention strategies towards sustainable utilization of rangelands. More work needs to be done on the rangelands which are major contributors to the livestock production industry in the country which feeds into the national herd. Past work on rangelands did not put much effort on communal rangelands. Most of the energy and time were spent on rangelands owned by the former largescale commercial farmers (LSCF) who were mostly white and to enhance their sustainability, while communal rangelands were left behind.

2.8 Livestock populations on semi-arid communal rangelands

Semi-arid rangelands of southwestern Zimbabwe are the hub of livestock production (Gamoun et al., 2015) by virtue of being in agro-ecological regions (AER) IV and V (Mugandani et al., 2012). Communal farmers keep a wide range of livestock including; cattle, sheep, goats, donkeys and poultry (Mashoko et al., 2007; Tavirimirwa et al., 2013; SRCLA, 2020), from which many benefits are derived in the form of products, by-products and services (Hargreaves et al., 2004). Farmers keep varying numbers of livestock species for various reasons such as animal draft-power from cattle and donkeys, milk, meat and manure from cattle, sheep and goats. Large numbers of livestock species such as donkeys and sheep kept by farmers are often blamed for being the major drivers of overgrazing and rangeland degradation (Pers. Communication). In the southwestern parts of the country donkeys are used for draft-power, so nearly every household keeps them. Donkeys and other livestock species kept in large numbers in the area, heavily utilize rangelands, causing serious degradation. As a result, the rangelands are no longer producing enough biomass, and will continue to decline further worsening feed shortages.

2.9 Degradation on semi-arid communal rangelands

Degradation is the worst problem ever to affect semi-arid communal rangelands (Reynolds, 2013) due to several years of unsustainable grazing management systems or the complete lack (Sasaki et al., 2012; Rutherford and Powrie, 2013). As a result of poor grazing management practice over the years, biodiversity loss is quite apparent on semi-arid communal rangelands (Senda et al., 2020) and the malpractice is reducing rangeland vigor (Kassahun et al., 2008; Bennett et al., 2012). Consequently, species composition and diversity are declining (Ibanez et al., 2007) and *Aristida barbicollis* now dominate the rangelands. This is a sign of rangeland degradation (Gibbs-Russell et al., 1991; Chippindal and Cook, 1976; Hlatshwayo, 2017). Broad-leafed grass species responsible for good animal development were grazed to extinction (Day et al., 1997). The species are mostly perennials whose benefit is not only limited to grazing but to protection, maintenance and balance of ecosystems and rangeland health.

Table 2.2: Vegetation species in the soil seed bank of a degraded semi-arid communal rangeland

Species	Growth habit		Type		Forage value	
	Perennial	Annual	Grass	Forbs	Good	Poor
Apium leptophylum		X		X		X
Aristida barbicollis		X	X			X
Borreria scabra		X		X		X
Brachiaria deflexa		X	X			X
Chloris virgata		X	X		X	
Cyperus angolensis		X	X		X	
Eragrostis viscosa		X	X			X
Fimbristylis dichotoma		X	X			X
Ipomoea alba		X		X	X	
Panicum novermnerve		X	X			X
Schmidtia pappophoroides	X		X		X	
Tragus berteronianus		X	X			X

Source: Hlatshwayo, 2017

Extinction of good grass species on semi-arid communal rangelands need not be blamed solely on poor rangeland management practices (Anderson and Hoffman, 2007; Gamoun et al., 2015). Climate change and variability also added their foot prints on the complication (Hein, 2006; Galvin et al., 2004). Several parameters on the rangelands have been affected, and the soil seed bank is the worst casualty (Gomaa, 2012; Karubian and Duraes, 2009; Liu et al., 2016). Soil seed banks are responsible for species perpetuation and persistence (Saatkamp et al., 2014). However, following several years of unsustainable utilization (Deng et al., 2013), recurrent droughts and climate change and variability (Ebei et al., 2007) semi-arid communal rangelands' soil seed banks are failing to facilitate plant species regeneration. The problem is mainly attributed to inadequate replenishment, and degradation is now a pressing matter, disrupting rangeland sustainability and capacity to supply grazers with adequate fodder (Ash et al., 2011). Rangelands are currently dominated by annual grass species, which apart from being unpalatable, produce low biomass and cover and cannot support livestock production (Mestdagh et al., 2003). There are several forbs species (non-graminoid herbaceous vascular plants) on the rangelands whose forage value is poor and are not useful to animals (Siebert and Dreber, 2019). Some of the not so good plants have become invasive compromising the productive potential of the rangelands. However, despite their poor forage value, the forbs contribute immensely to biodiversity on rangelands and survive due to their ability to tolerate adverse conditions and disturbances on the micro-environment (Buitenwerf et al., 2011; Trollope et al., 2014). The presence of unpalatable forbs on semi-arid communal rangelands is evidence of palatable species in the past (Siebert et al., 2020) which were grazed to extinction due to the overgrazing and overstocking (Young et al., 2013; Odadi et al., 2007; Kimuyu et al., 2017). As in the case of *A*. *barbicollis*, certain forbs species on the rangeland indicate degradation which is common on semi-arid communal rangelands of southwestern Zimbabwe (Siebert and Dreber, 2019).

Soil erosion is a menace and a pertinent issue to ecosystems in semi-arid areas. Rangelands have been stripped away of cover protecting them due to several years of heavy grazing (van der Waal, et al., 2011). They have become degraded, and tons and tons of top soil with its nutrients is being washed away annually leaving behind infertile soil which fails to support plant life (Palmer and Bennett, 2013). Several human activities carried out on rangelands are expediting the condition. Productivity and sustainability of rangelands is compromised, exposing them to the vagaries of forces of nature which are now wreaking havoc on the future of the rangelands. Some anthropogenic activities trigger soil erosion, run-off water washes away soil and its nutrients, ending up in the Indian Ocean on the Mozambican coast to feed aquatic life. For the sake of the rangelands' future corrective interventions to stop erosion need to be undertaken, this is one "export" that rangeland users do without gain (Hlatshwayo, 2017). Instead, the Mozambicans benefit from the Zimbabweans' silly mistake. The sad reality is that when the Mozambicans sell sea products, they never stop to think that some Zimbabweans also took part in feeding them. Only proper and sustainable rangeland utilization methods are the panacea to the plethora of problems affecting semi-arid communal rangelands of southwestern Zimbabwe. The sooner communal rangeland users start to think about conserving their natural resources (van Coller et al., 2018) the sooner the rangelands will start to recover and stabilize.

However, as the situation stands currently, destruction of natural resources is quite high and it is not good enough for extensive livestock production, which depends on rangelands.

Another matter of concern complicating the state of further degradation, is the proliferation of too many woody species, forming bush encroachment on semi-arid communal rangelands (Ward et al., 2014; Buitenwerf et al., 2012). Bush encroachment like rangeland fragmentation (Senda et al., 2020; Clavijo et al., 2005; Tessema et al., 2014) reduces grazing space considerably (Higgins and Scheiter, 2012; Moncriefff et al., 2014). This further worsens feed shortages, which are an annual phenomenon on semi-arid communal rangelands (van Langevelde et al., 2003). Bush encroachment has several negative effects on rangelands; (i) It uses up a lot of moisture, (ii) It is not aesthetic (iii) It suppresses growth of the under layer (Ward and Esler, 2011) and (iv) It makes movement impossible for both humans and animals. Therefore, on semi-arid rangelands, bush encroachment reduces biomass production further, which for decades has been low due to climatic and anthropogenic factors (Puttick et al., 2014).

The exponential increase in woody species on rangelands is not only limited to communal areas in semi-arid southwestern Zimbabwe, but is cause for concern worldwide (Archer et al., 1995; van Auken 2009). While there are many explanations for bush encroachment causes, in the context of semi-arid regions of Zimbabwe, two major drivers come to mind; (i) Grazing pressure and (ii) Climate change and variability (Spinage, 2012). Following several decades of inappropriate utilization methods, semi-arid communal rangelands became degraded (van Langevelde et al., 2003) and many changes occurred on the ecosystems (Stuart-Hill and Tainton, 1989; Spinage, 2012). Summed up, the changes render semi-arid rangelands of southwestern Zimbabwe incapable of supplying adequate fodder to grazers. Therefore, in order to satisfy the rising global demand for food from animal products and by-products semi-arid communal rangelands of southwestern Zimbabwe, which at this stage are can be likened to sleeping giants, must wake up and take up their rightful position in supporting extensive livestock production. This is now the time, to rejuvenate degraded rangelands and restore productivity, so they continue to support livestock production, which in turn will guarantee livelihoods and food security in the smallholder communities. This is a welcome intervention as dry land crop farming fails to guarantee food security due to recurrent droughts, poor soil fertility and climate change and variability (Murungweni et al., 2016).

2.10 Restoration of degraded communal rangelands

Semi-arid rangelands worldwide, are caught up in a myriad of problems (FAO, 2010, Senda et al., 2020) The net effect of the problems is low biomass mass production falling far too short to satisfy livestock feed requirements for a year. Allowing this to continue unchecked, reduces livestock production in semi-arid communal rangelands, having spill-over effects on livelihoods and food security dependent on livestock production. Enough evidence is available proving that semi-arid communal rangelands are degraded (Bai and Dent, 2006) following decades of heavy utilization, overpopulation and climate change effects (Reid et al., 2010). Overgrazing on communal rangelands, lowers soil-seed bank viability (Hlatshwayo, 2017) due to poor replenishment inhibiting plant population dynamics and stability (Zuloaga-Aguilar et al., 2016). Due to declining biodiversity on ecosystems, herbaceous species are now dominated by annual plant species of both grasses and forbs whose forage value is poor (Gemedo-Dalle et al., 2006). The implication is that restoration must be performed as remedial intervention (De Groot et al., 1992) to revive the rangelands and nurture them to continue to feed livestock into the future (Galvin et al., 2002).

Rangeland restoration means bringing back a degraded rangeland to its prime productive state, while providing fodder to livestock (Brown and Bugg, 2001). It can be undertaken in two ways: (i) Dispersing seed manually or mechanically (Scholz, 1995); seeds of different grass species mixed are manually broadcasted on an affected area and (ii) Seed dispersion using animals as a medium to spread seed on an affected area via dung (Ash et al., 2011; Saunders et al., 1993). Both seed dispersal methods, can potentially recharge the soil-seed bank and enhance plant population dynamics and stability (Gomaa, 2012; Christoffoleti and Caetano, 1998). A productive rangeland is necessary especially in semi-arid regions where livestock production is a key agricultural activity contributing to people’s livelihoods and food security. The agricultural activity is not very sensitive to the adverse effects of droughts. Generally, droughts occur frequently in semi-arid regions. Encouraging herbaceous vegetative growth on the rangelands increases fodder availability, hence livestock production is boosted.

2.10.1 **Mechanical seed dispersion**

Semi-arid rangelands of southwestern Zimbabwe are important in the livelihoods of many resource poor communal people. They perform many functions such as providing grazing to livestock (Boval and Dixon, 2012), food for humans in the form of wild fruits, wild vegetables, mopani worms and many others as well as services such as medicines, firewood and so forth (Abtew et al., 2012; Adam et al., 2013). However, over the years the rangelands have been struggling to provide enough grazing to livestock, due to high levels of degradation caused by climatic (recurrent droughts) and human factors (over utilization and continuous grazing) (Abebe et al., 2012; Anderson and Hoffman, 2007). Major changes in species occurred resulting in poor replenishment of the soil-seed bank whose major function is to perpetuating vegetation species and building rangeland resilience (Mestdagh et al., 2003).

Demand for animal products and by-products continues to rise worldwide, requiring rangelands to maintain a balance between fodder requirements and livestock productivity (Ash et al., 2011). This can be achieved through remedial interventions such as re-seeding to reverse degradation, one of the causes of biodiversity loss, poor species composition and low rangeland productivity (Bai and Dent, 2009). Through rejuvenation, rangelands can continue to feed livestock and support food security and livelihoods in semi-arid regions where annual failures characterize crop production. Scientific proof points to low seed reserves in the soil-seed banks, indicated by low species diversity on communal rangelands (Christoffoleti and Caetano, 1998; Hlatshwayo, 2017). Available species are mostly annuals lacking the ability to support livestock production, hence the need to re-introduce leafier and palatable perennial grass species suited for livestock production (Boval and Dixon, 2012)

2.10.2 **Requirements for mechanical seed dispersion**

Grass is the most important crop to a livestock farmer (Mestdagh et al., 2003), it is the stuff that animals convert into all the useful products and by-products such as meat, milk, money, animal-draft power and so forth, necessary in people's lives (Palmer and Bennett, 2013). Therefore, degradation must be reversed as it reduces seed and biomass production. Seed is a major input guaranteeing mechanical seed dispersion success on degraded land (Saunders et al., 1993; Scholz, 1995). It can be derived by ensuring that every year, mature seed of different grass species is harvested during the peak growing season (February – April) and stored under shade awaiting processing and use. The seed must be handled with extreme care to retain viability, under no circumstances should it be exposed to direct sunlight which causes poor germination. After processing, it is stored in vermin and moisture-proof containers waiting for time for rejuvenating degraded rangelands (Liu et al., 2016).

2.10.3 **Key aspects of restoration**

Rangeland regeneration occurs naturally to a certain extent however, degraded land will rarely revert to its original condition. More often than not, degradation may worsen first before recovery, so restoration action is necessary for speeding up the restoration process (Brown and

Bugg, 2001). To conduct successful restoration, four aspects must be fulfilled: (i) Identifying the cause and effect of degradation; rangeland degradation does not happen spontaneously but caused by something which must be identified first and addressed (Boval and Dixon, 2012). For instance, in semi-arid communal rangelands, soil-seed banks are depleted, so to bring back desirable species on them, manual/mechanical re-seeding is necessary (Mestdagh et al., 2003). (ii) Stabilizing the site; after identifying the cause, further damage on the site must be reversed or stopped. This allows remedial interventions to be effective in order to benefit the ecosystem's biodiversity and natural balance. (iii) The degraded environment needs reconstructing; in the case of rangelands, their prime function is to provide animals with grazing, however, this ceases to occur once land becomes degraded. There will be changes in species diversity and forage value (Hlatshwayo, 2017), efforts to rebuilt species diversity and rangeland vigour require the support of manual seed dispersion. Seeds of different grass species mixed together having many perennial species must be re-introduced into the herbaceous species communities of degraded sites (Ash et al., 2011, Liu et al., 2016). (iv) Monitoring; is a key aspect in the restoration process making it easy to take stock of progress on the exercise. Without monitoring, it will be hard to measure success of interventions conducted on the degraded land.

The ultimate goal is building rangeland resilience and productivity of semi-arid communal areas, where these biomes are vital to supporting livestock production, which is famed for supporting food security and livelihoods. In semi-arid regions where dry land crop farming usually fails, livestock production is a better agricultural option. Food insecurity is mitigated through livestock production because the agricultural activity is less sensitive to droughts which are frequent in the regions.

2.10.4 **Benefits of restoration**

Land is an important factor of production, societies' livelihoods dependent on it, 99.9% of the food humans consume is derived from it and more than 50% of the world's GDP comes from it (Patro, 2021). Therefore, degraded rangelands are not productive and cannot fulfill their obligation to livestock and humans (Shackleton and Gambiza, 2008). However, through restoration, degraded land can be rejuvenated (Scholz, 1995; Saunders et al., 1993). Restoration has many benefits on the land, some of which are listed below;

- Improvement of biodiversity; reseeding is conducted using mixed seeds of different plant species. This improves species composition and diversity especially in cases where some species had become extinct (Boval and Dixon, 2012).

- Improvement of infiltration; run-off is high on bare ground due to low infiltration a restored site gains good cover which increases infiltration. Underground water bodies get replenished by increased infiltration.

- Restoration ensures food and water security, animals whose products and by-products are important in humans' lives of depend on plants for food. The abundance of plants on rangelands ensures animal productivity. Besides, prime land is productive which benefits humans.

- Reduction of emissions (greenhouse gases such as carbon dioxide have a negative implication on the climate due to corrosion of the ozone layer resulting in global warming).

2.11 Livestock mediated seed dispersion

Land and animal interaction, dates back a long time (Liu et al., 2016. Animals ingest plant materials in order to satisfy their energy requirements (Boval and Dixon, 2012). The interaction is very symbiotic or mutual as the land benefits from animals and vice versa. During feeding animals select and pick plant species they want to eat (Mestdagh et al., 2011) and at the same urinate and drop dung used by plants for their energy requirements (Anderson and Hoffman, 2007; Bakker, 1989). Further to enhancing and maintaining soil fertility, animals play a critical role in perpetuation and persistence of plant species. Great strides have been made in understanding better, seed dispersal by wind, yet animals are equally critical in dispersing seeds (Cousens et al., 2010). The seed dispersal process is critical for plant diversity (Jones, 2017). In semi-arid communal rangelands, the influence of where animal mediated seeds land, is not well understood but is critical in maintaining plant diversity (Karubian and Duraes, 2009). Degradation and biodiversity loss on semi-arid communal rangelands are major problems which disrupt animal seed dispersal, especially where animals shun badly degraded areas (Jones et al., 2017). Despite limitations associated with animal-mediated seed dispersal in communal rangelands, the method still stands out as a good medium and option for restoring degraded rangelands.

2.12 Fodder production, conservation and utilization in semi-arid communal areas

Scientific evidence proved that semi-arid communal rangelands are derelict due to several years of abuse (Tessema et al., 2014; Senda et al., 2020). Currently, as things stand, there is no hope in sight that rangeland condition will improve naturally any time soon, more so with climate change expediting the complexity. It is incumbent upon users, researchers and policy makers to think outside the box and come up with strategies to achieve sustainable rangeland utilization. The rangelands have a huge obligation ahead, of supporting livestock production which is a flagship of food security and livelihoods in semi-arid regions where annual failures always blight crop farming (Adam et al., 2013; Abtew et al., 2012; Thornton et al., 2015). The long-term solution to feed shortages and good rangeland condition in semi-arid communal areas lies in production and utilization of fodder crops for dry season supplementation (Al-Hashmi, 2008; Al-Karaki and Al-Hashmi, 2011). Fodder crops have the potential to reduce over reliance and grazing pressure from rangelands, for communal farmers who have limited options of livestock feed sources. Therefore, the two major animal feed sources; rangelands and planted pastures must complement each other in providing livestock with reliable fodder-flow.

2.12.1 **Family groups of fodder crops**

Fodder crops can be defined as crops grown for purposes of feeding livestock. They are composed of two main families; Poaceae where all fodder grasses belong, for instance Rhodes grass (*Chloris gayana*), Mombasa (*Panicum maximum* cv. Mombasa) Fox-tail grass (*Cenchrus ciliaris*) and Brachiaria (*Brachiaria brizantha* cv Pilata) (Carlier et al., 2009; Maass et al., 2015; Njauri et al., 2016; Kumar et al., 2022) and forage sorghums which are most suited for dairy animals. Examples of forage sorghums include Nutritop, Sugar graze and Sugar drip. The Leguminosae family includes legumes such as Lablab (*Lablab purpureus*), Velvet beans (*Mucuna pruriens*), Siratro (*Mircoptilium atropurpureum*), Lucerne (*Medicago sativa*) Cowpeas (*Vigna unguiculata*) and Sunhemp (*Crotalaria juncea*) (Ekepu and Tirivanhu, 2016; Semba et al., 2021; Beuselinck et al., 1994; Bhagawati and Paul, 2021). Fodder legumes are classified under two groups; herbaceous fodder legumes which have already been mentioned and tree legumes which include *Acacia angustifolia*, *Leucaena lucocephala* and Moringa (*Moringa olifera*) to name just a few. Legume trees are good sources of browse especially during the dry season when the rangelands would be offering low quality and quantity feed. Both fodder grasses and legumes play an important role in the nutrition of animals, as grasses are good sources of crude fibre which supplies energy (MacDonald et al., 2010) while legumes are a good source of crude protein which is responsible for the development and growth of an animal and digestion of acid fibres (Beuselinck et al., 1994). Lack of feed requirements such as crude protein and crude fibre in animal diets can affect the performance of affected animals and cause poor animal body condition and reproduction.

2.12.2 **Advantages of fodder crops**

Fodder crops have several advantages making them better feed materials more so for livestock farmers in semi-arid communal areas of the country where they fill the feed deficit gap. Fodder crops can adapt to a wide range of soil types, are easy to grow, they grow fast and they produce high yields (Prakashkumar and Sreenath, 2019). The attributes make them more suited to semi-arid communal areas where rangelands produce low biomass. Fodder crops are very palatable and nutritious and fodder grasses such as Giant-Juncao grass (*Pennisetum purpureum* x *Pennisetum typhodium*) and Bana grass (*Pennisetum purpureum*) can contain up to 10.8% CP at six weeks of growth while forage legumes such as Lablab (*Lablab purpureus*) can have 26% CP and Lucerne (*Medicago sativa*) also known as the Queen of forages contains 30% CP at flowering stage (CIAT and CGIAR, 2015). Unlike natural pastures, where some plant species have poor forage value and are generally shunned by grazing animals which usually select and pick what they like to graze leaving out those species they don't like, fodder crops are highly palatable and readily accepted by all livestock species at any stage of growth. Fodder crops enable farmers to offer cheap supplementation to their livestock, compared to commercial stock feeds which are way out of reach of communal farmers most of whom are resource constrained. Adoption of fodder production in semi-arid areas which are characterized by annual deficits can improve livestock feed availability. The positive attributes of fodder crops make them the crops of choice as they have the potential to make the future of extensive livestock production sustainable as it is currently under threat from feed shortages.

2.12.3 **Production mode of fodder crops**

The two major fodder groups discussed above Poaceae/ graminoids and Leguminosae can be produced under both dry land farming and irrigation with a good measure of success, although higher biomass yields produced under irrigation are the only noticeable difference (Al-Hashmi, 2008; Al-Karaki and Hasmi, 2011). However, fodder production in semi-arid regions must focus on fodder crops suitable for dry land production only. This is mainly because the majority of farmers in semi-arid communal areas have no capacity to irrigate their crops as they depend entirely on rainfed agriculture (Phiri et al., 2019). However, one worrisome observation is low fodder production in Zimbabwe, especially in semi-arid communal areas. Uptake of the technology is slow, despite the need, to permanently solve perennial feed shortages which are so common in the regions.

2.12.4 Uses of fodder crops

The major purpose for growing fodder crops is to feed livestock, although fodder can be produced as an income generating enterprise. The crops are handy in semi-arid regions where rangelands produce little natural fodder falling far short of annual animal feed requirements. Fodder crops can be used according to the farmer's preferences and needs. There are many ways of using fodder crops (Beuselinck et al., 1994), these include grazing especially for fodder grasses such as Mombasa (*Panicum maximum* cv. Mombasa), Rhodes grass (*Chloris gayana*), Tanzania (*Panicum maximum* cv. Tanzania), Tifton grass (*Cynodon nlemfuensis*) and Fox-tail grass (*Cenchrus ciliaris*) (Maass et al., 2015) or mowed for hay or ensiling (Musalila et al., 2016). Cut-and-carry is also another method of utilizing fodder crops, involving cutting the fodder and taking it to the animals to feed them. This is mostly used on fodder crops such Bana grass (*Pennisetum purpureum*) where grazing may weaken the stand, therefore to avoid the challenge, the grass is harvested fresh and taken to the feeding pens and given to the animals. However, cut-and-carry does not address the issue of feed shortages which occurs every year mostly during the dry season.

2.13 Preservation methods of fodder crops

Growing fodder crops aims to enhance dry season supplementation as during this period, semi-arid communal rangelands will be at their lowest ebb. The rangelands are characterized by low productivity which induces feed shortages annually, getting worse during the dry season (Abebe et al., 2012). Some past feed shortages caused huge livestock losses compromising livelihoods and food security dependent on livestock production (Bo et al., 2013). As an adaptation strategy against annual feed deficits, farmers must produce fodder crops to preserve them and create fodder banks for use during needy times. To create fodder banks, the crops are preserved in two forms; (i) Dry form to prepare hay (Hussain, 2018), and (ii) Fresh form to prepare silage (McAllister et al., 2017). Choice of preservation method is the farmer's responsibility the farmer chooses a method that suits their conditions and capabilities. However, farmers with the necessary resources can opt to use both forms of fodder preservation when they choose to create their own fodder banks.

2.13.1 Desirable characteristics of fodder crops used for hay making

Fodder materials must have certain desirable qualities ideal for hay making when the time to preserve them is ready (Musalila et al., 2016). The fodder materials must be easy to cut, it must not be cumbersome to accomplish. If they are difficult to work, they are unsuitable for hay making as it would be difficult and expensive to make. According to the definition, hay is cut and dried grass, fodder legumes or other plants, hence, the ability of cut fodder materials to dry is a critical requirement when choosing fodder materials for hay making (Hussain, 2018). Yield is another characteristic to consider when making hay, fodder materials such as Lucerne (*Medicago sativa*), Brachiaria (*Brachiaria brizantha*) and Mombasa (*Panicum maximum* cv. Mombasa) produce 40t DM/ha per year making them ideal for hay making (McAllister et al., 2017). The last factor to consider is the fodder plants' ability to regrow after cutting or mowing. Fodder crops listed above, form what are generally referred to as permanent pastures, as stands of these fodder plants have a life span exceeding twenty years. During all the subsequent years, only harvesting is done as there is no need for establishing new fodder.

2.14 *Hay*

Hay can be defined as cut and dried grass, forage legumes or other herbaceous plants, and stored in a barn or fodder bank for feeding livestock such as cattle, sheep, goats, horses and others such as rabbits and guinea pigs. However, it is important to note that hay alone is not a complete feed as it is used as a supplement during lean periods such as the dry season when rangelands offer little feed of poor quality (Hussain, 2018). Hay is preserved during the peak growing period when fodder plants are nutritious and plenty. It is suitable for communal farmers who are usually resource constrained as it is easy to prepare, keep and use.

2.14.1 **Importance of hay**

Hay has many benefits, making it an important feedstuff, providing high quality nutrients because it is usually cut when the nutrient content is at its optimum level (CIAT and CGIAR, 2015). During lean periods, hay it makes it possible for farmers to give their animals high quality supplementary feed that helps animals to maintain good body conditions. The dry feedstuff improves the management of both planted and natural pastures by: (i) Reducing over reliance on natural fodder thereby allowing rejuvenation of grazed fodder plants. This ensure the control of over utilization of rangelands leading to degradation especially in semi-arid communal areas. (ii) Cutting or mowing prevents accrual of moribund stuff, which causes the death of tufts especially of plants of the poaceae family. Mowing/ cutting, enables planted fodder crops to produce fresh and highly nutritious feed for livestock.

2.14.2 **Hay making**

Hay making enables the capture of nutrients in fodder materials in a storable form so that they become available as fodder feed during the dry season (Prakashkumar and Sreenath, 2019). Timing is a critical aspect in hay making as the process must coincide with the right stage of plant growth and weather conditions to achieve desirable results (Fraccarolli, 2015). The value of nutrients is greatest during the early growth stages of plants, as during this time plants put most of their energy into vegetative growth resulting in high concentrations of starches, proteins and minerals. The hay making process starts with cutting or mowing (Prakashkumar and Sreenath, 2019), and this is determined by the maturity of forage plants which should be in their early vegetative stages. Timing of the process must be made in such a way as to coincide with the most reliable weather forecast. However, for best results fodder materials must be cut in the morning to allow them to gain more hours of drying time.

When the forages are cut, tedding follows, this process involves an equipment with power takeoff, which is made to throw fodder materials gently into the air to speed up drying. The stage can also be done manually in the absence of machinery, where the process is carried out by resource constrained communal farmers. When the fodder dries up, it is raked. Once all the dried fodder materials are raked, baling is the final stage in the hay making process. Hay bales can be made in any shape (square, rectangle or round) according to the farmer’s preference. When baling is complete, the hay bales are ferried to a fodder bank for storage. The major determinant factor in the quality of hay is moisture, too high or too low of it spoils the product. High moisture content causes spoilages due to accumulation of fungi, while too little moisture increases the risk of fires which easily destroy stored hay (Fracarolli, 2015).

2.14.3 **Causes of losses in hay**

Hay making aims to create fodder banks for mitigating feed shortages during lean periods, however, several factors can disrupt achieving this objective. Stomping is a cause of losses in hay, which happens when animals are allowed to graze on a site before fodder plants are cut for hay. As the animals move all over the area during grazing, some of the fodder plants are destroyed by hoof action and the damage is becomes extensive due to large numbers of grazing animals. The other factor of concern in hay losses, is leaf-fall. As plants grow old, some of their parts such as leaves tend to dry off and eventually fall down and become plant debris. The more the leaves fall down, the less the hay harvested, as only the culms will be remaining, and most of them will have lignified and lost nutritional value. The other loss of hay is caused by chemical deterioration during the growing stages of the fodder plants. Fodder plants more so from the Poacea family are very nutritive during the early stages of growth (Maass et al., 2015). However, as they grow older carbonification and lignification set in, reducing the nutritive value of the plants. Lastly, hay loss is also caused by fecal contamination, animals urinate and drop dung on standing fodder plants during grazing and movement. When this happens, animals tend to shun the contaminated plants. Huge amounts of hay get lost during the period animals graze in large numbers.

2.14.4 **Factors affecting hay under storage**

Temperature is a very important factor in storing good quality hay because it must remain below 50^0C, which is considered as normal (Fraccarolli, 2015). When temperatures range between 50^0C and 60^0C, farmers with hay in their fodder banks are advised to exercise caution because the hay is prone to fires. Stored hay is at more risk of fire when temperatures exceed 70^0C.

2.15 Silage making

Silage can be defined as the product of fermentation of given fodder materials under anaerobic conditions in an environment called a silo. Silage making is another way of preserving fodder materials to mitigate fodder shortages during the dry season (Musalila et al, 2016). This type of feedstuff is suitable for semi-arid communal areas as it is a risk reduction strategy in livestock production in semi-arid regions. Silages allow feedstuffs prepared from fodder materials to be kept in fresh, because it has long shelf life of up to twenty years. However, silage is mostly suited for dairy enterprises, although it can also be used to feed other species of farm animals such as beef cattle (Borreani et al., 2017). Although silage is a type of feed prepared from fodder materials, it is not ideal for use as a sole diet, but suitable for supplementation. The ensilage process dates 3000 years back, during the ancient times when livestock farmers saw to the need to preserve fodder materials in fresh form (Coblentz and Akins, 2018). On the African continent, the Egyptians started making silage as far back as 2000 BC (McAllister et al, 2018), and it is still being made to date because of evolution in the silage making process. This was made necessary because feed was abundant during the growing season, but tailed off during winter months causing anxiety and challenges to farmers in sourcing good quality feed for livestock during lean periods. As a long-term solution to the feed crisis, early people came up with the silage making technology (Avila et al., 2010), through which feed was preserved in fresh form and used when the need arose. The technology has been perfected over time and is still being used today for the betterment of livestock production systems (McAllister et al., 2017).

2.15.1 **Advantages of silage**

The major constraint affecting livestock production in semi-arid areas is feed shortage during the dry season (Abebe et al., 2012), however, silage making and its use as a supplement in animal diets addresses this issue. Several advantages that can be derived from using this type of feed, first, it guarantees feed availability throughout the whole year, ensuring animals maintain good body condition and health (Kumar, 2016). Silage is a type of feed which animals efficiently utilize to their advantage, making it a superior supplementary feedstuff which any fodder bank must have. During the ensilage process, fermentation takes place catalyzing bacteria to act on cellulose and carbohydrates found in the forages resulting in the production of volatile fatty acids (VFA) which include acetic, lactic and butyric acids (Kumar, 2016; Borreani et al., 2017) Further evidence of silage being a good feedstuff, is demonstrated by its ability to minimize nutrient losses, a challenge which is commonly related to other feedstuffs such as hay where losses as much as 30% of the dry matter (DM) may be incurred (Borreani et al., 2017). d After ensiling, silage can keep in a stable condition for longer periods (Kumar,2016), some silages are known to have life spans extending from five years to as long as twenty years. In environments such as the semi-arid regions where climatic conditions are unpredictable affecting rangeland productivity, the feed comes in handy when animals run short of feed more so in the event of serious droughts which are not very uncommon.

2.15.2 **Disadvantages of silage**

Although many merits of silage have been discussed, the feedstuff has disadvantages, which blight its merits. The ensilage process, requires a silo, which involves construction of a permanent structure for the good of the end product. Compared with other simpler field methods of curing and storing feedstuffs such as hay, silage comes with added costs, making it expensive for communal farmers. Since most smallholder farmers in the semi-arid regions are resource constrained, silage making may be way out of reach of many farmers in this category (Adesogun, 2009). A lot of care is required during the ensilage process, without which more wastages are incurred if the product is not properly prepared. Further to losses, livestock reject badly prepared silage, meaning an affected farmer wastes time and resources to prepare feed animals won't eat. The objective of preserving a feedstuff is to mitigate feed shortages, but they remain unresolved when the feed goes bad leaving animals to continue suffering.

Fermentation of chopped fodder materials resulting in silage, takes place in an environment called a silo, where sunshine does not access. This causes a significant reduction in the amount of vitamin D in silages, and compared with sun dried feedstuffs such as hay, it is inferior. Further to lowered nutritive value associated with silages, is the issue of cost which is two pronged: (i) Inoculants required to enhance fermentation, do not come cheap, money has to be forked out to procure additives and (ii) Silo filling up during silage making process requires extra labour, this adds an extra cost to silage preparation. The third cost is incurred through transportation of harvested fodder materials and when all costs are factored in, silage making becomes expensive for communal farmers. In principle silage making is supposed to be affordable since farmers in semi-arid communal areas badly need feed for their livestock during the dry season, however, the farmers have no money for undertaking silage making.

2.15.3 The silage making process

The silage making process is very much dependent on timing, such that fodder materials must be cut just before they are fully mature, as this is the period when the level of nutrients is at its highest. The ensilage process must make sure that the end product is as nutritious as possible (Adesogun and Newman, 2014). Therefore, harvested forages should be allowed to wilt in the field for at least six hours to drain effluent to the optimum level which is pegged at 60 – 75%. However, extreme care must be exercised during the wilting process, so that the fodder does not become either too dry or rained on. Both events are not desirable as they reduce efficiency of the fermentation process, it is pertinent to remember that fermentation plays a significant role in silage which is the end product (Adesogun, 2009).

Before the silage making process begins, a silo supposed to be prepared and made ready. Four basic steps follow silo preparation; first fodder is cut/ harvested, wilted and transported to the silo. Excess effluent draining of fodder materials should not exceed DM of 70- 80% as this may result in haylage formation thereby compromising silage quality (Borreani et al., 2017). Second, fodder materials are chaffed, squashed and chopped to pieces between 2 and 4cm long, which is the preferred size. The size of chopped fodder materials enhances packing density which is favoured by the (LAB) lactic acid bacteria (Bolsen, 2006). During chaffing, a fermentation mixture comprising six constituents (molasses, salt, mineral mixture, DCP, LAB and Urea) should be ready and added to the fodder materials in small quantities (Brusetti et al., 2008). Third, the pit is filled with chopped fodder materials and compacted. This step is very necessary, it aids in expelling air from the chopped fodder materials. It needs no emphasis that fermentation of chopped fodder materials should take place in anaerobic conditions in a silo. The presence of air in silage encourages the growth of moulds, causing it to rot or spoil. Animals do not accept spoiled silage therefore, farmers need not waste time, money and fodder materials preparing feedstuffs that will go to waste. The purpose of ensilage is to prepare for dry season feeding, however, this may not happen when the silage spoils during the fermentation process. Fourth, the silo is covered with polythene material, tucked in as tightly as possible to exclude air. Silage maturity takes 30 – 40 days, thereafter one side can be opened, and silage enough for a day’s ration taken out at a time. It is important to understand that once the pit is opened up, silage use must be done as soon as possible to avoid spoilages due to deterioration rendering it unacceptable to livestock.

2.15.4 Attributes of good quality silage

The essence of preserving green fodder materials by way of chaffing and fermenting them under anaerobic conditions is to produce good quality feed called silage. In order to determine Good quality and mature silage is determined by the satisfaction of four requirements (Adesogun, 2010). First, the silage must be free of moulds, which usually occur during the pit-filling and compaction process, if they are poorly done. Second, good quality silage produces a sweet smell or a sour taste and thirdly, its colour must always be faint green or brownish however, poorly prepared silage changes to a black colour. Fourth, good quality silage is determined by pH that should range from 3.5 to 4.2. A silage that meets all the four characteristics above, is deemed good quality, and readily accepted by livestock.

2.15.5 Factors influencing quality of silage

Products produced for utilization or sale have to meet certain quality standards to make them acceptable and this also applies to silage. While caution is exercised during ensilage to ensure the end product is of good quality, eleven factors influence quality in a silage (Borreani et al., 2017). First; Grass type and variety, it is always important when using some grass types for ensilage to remember that as soon as they are cut or harvested, certain grass types start losing their sugars (Muck and Dickerson, 1988). This problem is mitigated by selecting varieties that take a little longer to lose their sugars. Second; Grass sugar content, the LAB, (lactic acid bacteria) feed on sugars for them to cause fermentation in fodder materials, therefore, grass varieties that quickly lose sugar content are to be avoided. Three; Stage of growth, grass cut for ensilage must be mature enough, harvesting it a little too early reduces crude fibre content, which influences silage quality.

Four; Dry matter (DM) at ensiling, it is key to dry the fodder materials to an appropriate dry matter level to enable ensiling to be conducted as soon as possible. However, over drying fodder materials makes compacting or packing difficult, due to air pockets which lead to spoilage (Adesogun, 2010). Fife; Length of chopped fodder material pieces, the ideal length is 2 – 4cm. Anything longer than this makes compacting hard, in any case longer pieces cannot release adequate sugars to feed the LAB (Bernardes et al., 2017). Six; Contamination, usually happens when the silage starts to mould. The silage changes to a black colour as opposed to a greenish tint or brownish colour which is common in good quality silages, and animals reject poor quality silages.

Seven; Additives, a silage is never complete without them, lack of additives results in poor quality silage. Additives aid the activity of the LAB which cause fermentation in silages. Eight; Fertilizer, the choice of a fertilizer to apply when top dressing must be guided by results of recent soil tests. Although Sulphur (S) is important, the recommended amount to apply is 20kg/ha per harvest. The other fertilizer to consider as important is potassium (K). It is responsible for the construction of starch sugars and development of amino acids which are the building materials of protein. Nine; Speed of ensiling; the process must be completed in recommended time as taking too long to finish it, may cause the chopped forage material to dry up and cause both packing and fermentation difficult thus compromising the quality of the end product. Ten; Exposure to air; fermentation of chopped fodder materials is a process that should take place under anaerobic conditions, exposing chopped forage materials longer during ensiling may affect quality of the silage. Eleven; Feeding technique; silage can be compromised during feeding. Failure to practice due caution during silage removal from the silo and taking it to feed lots. Failure to tuck in the covering material tightly affects silage, allowing in air causes spoilage rendering the silage unfit for livestock. Still on the same note during feeding, only silage enough for a feeding session must be dug out of the silo. Taking out too much silage causes it to dry up due to exposure to the sun and air, once this happens, it ceases to be silage any more. Silage must remain in fresh form over a long period of time as long as it is kept under favourable conditions. All discussed eleven factors play a significant role in influencing the quality of silage. Under no circumstances should any of the factors be compromised as quality of silage is compromised. The objective of ensilage is to produce nutritious livestock feed for dry season feeding, this can only be achieved by properly adhering to factors influencing silage quality.

2.16 Summary of the literature review

This review of literature shows that numerous factors constrain semi-arid communal rangelands of southwestern Zimbabwe, hence they are now producing very little fodder. Over the years, feed availability on the rangelands, has been characterized by annual shortages, with severe cases causing huge livestock mortalities. Livestock production in semi-arid regions is a better agricultural option, significantly influencing food security and livelihoods, however, its future is doubtful due to low rangeland productivity.

The serious degradation on semi-arid communal rangelands of southwestern Zimbabwe is driven by high grazing pressure and lack of sustainable grazing management systems. Carrying capacities have decreased, due to a shift in species diversity and low standing biomass resulting from the depletion of soil-seed banks. The factors confirm the effects of consecutive years of poor soil-seed bank replenishment which is retarding regeneration, perpetuation and persistence of plant species. Sufficiently recharging soil-seed banks in communal rangelands can speed up rangeland rejuvenation and bring them to climax condition. Consequently, species diversity, biomass production and rangeland resilience will increase and guarantee stability to livestock production. Seed dispersion on the rangelands can be implemented in two methods: (i) Manually and (ii) Livestock mediated. Both methods produce good results, however, they have not been tested fully, to evaluate their effectiveness in restoring degraded rangelands.

Semi-arid communal farmers over rely on rangelands for livestock feed, which exerts high grazing pressure on the rangelands, however, this can be reduced significantly by adopting fodder production, preservation and utilization. The two major feed sources; rangelands and fodder gardens can complement each other in feeding livestock in the semi-arid regions all year round. As a matter of fact, two basic benefits accrue due to adopting fodder production, preservation and utilization: (i) Permanently solving the long-standing annual feed shortages problem, and relieve anxiety among livestock farmers (ii) Reducing grazing pressure on rangelands, and building resilience, increasing biomass production and bringing stability to extensive livestock production. Fodder production technology has not been adopted fully in semi-arid communal areas, despite evidence of its benefits to farmers. Harvested fodder materials can be preserved in two forms: (i) Dry form (hay) and (ii) Fresh form (silage). Both feedstuffs are suitable for fodder banking which enhances dry season feeding, an intervention that remained a pipe dream over the years. Performance and offtake of livestock will increase due to availability of disposable animals for sale on the market and families will get money to cater for their needs. Sustainably rangeland management efforts guarantee fulfillment of the farmers' ecological, social and economic needs. An evaluation of resource allocation to family needs serves purposes of assessing the impact of building resilience and productivity of semi-arid communal rangelands to stabilize livestock production which sustain food security and livelihoods. A structured questionnaire is the tool administered to the farming community in the study area to carry out the assessment.

CHAPTER THREE

3 Reseeding of a degraded communal rangeland in semi-arid savanna

3.1 Introduction

Rangelands can be defined as lands on which the native vegetation is predominantly grasses, grass-like plants, forbs or shrubs suitable for grazing or browsing whether in their climax or natural potential communities (Soder et al., 2007; Abate et al., 2010; Squires et al., 2018). Semi-arid rangelands occupy sixty-five percent of Zimbabwe (Mugandani et al., 2012). Their major role is to provide fodder to animals (Undersander et al., 2002; Abate et al., 2010), however, they also provide societal necessities such as wild fruits, vegetables, medicines and fuel which are important in the lives of resource constrained rural people (Abtew et al., 2012; de Sousa et al., 2018; Mahonya et al., 2019). In semi-arid areas, livestock production, is the better agricultural activity in the crop-livestock system of agriculture practiced, however, it is dependent on rangelands (Undersander et al., 2002; Steinfeld et al., 2006). Animals can accomplish life processes such as movement, digestion, foraging, work, growth and reproduction because of the energy, they derive from graminoids supplied by rangelands (Jones, 2017). Due to this reason grass communities must remain persistent and productive on rangelands, to benefit animal production (Boval and Dixon, 2012).

Low rangeland productivity is a major constraint to livestock production on semi-arid communal rangelands (Rutherford and Powrie, 2013). The poor rangeland performance is usually attributed to droughts (UNFCCC, 2008; Vetter et al., 2020) and mismanagement (Rohde et al, 2006), yet the soil-seed bank which is a major driving factor behind plant species regeneration is totally ignored, (Karubian and Duares, 2009; Shang et al., 2009; Saatkamp et al., 2014; Vandvik et al., 2016). Information on soil-seed banks of semi-arid communal rangelands is limited (Chambers and Mac Mahon, 1994; Skalova et al., 2019; Shi et al., 2020). In the southwestern semi-arid communal rangelands, Hlatshwayo (2017) reported serious depletion of the soil-seed bank. This and other factors contribute further to low rangeland productivity in the long run (Cingolani et al., 2005; Tarhouni et al., 2007). Livestock in these regions experience feed shortages which have evolved into an annual phenomenon over time (Reid et al., 2010). Animal movement and interaction with plant species communities alter the composition of species (van der Waal et al., 2011), which subsequently affect the soil-seed bank (Karubian and Duraes, 2009; Tessema et al., 2011). One of the after-effects of the animal-plant interaction is rangeland degradation (Sasaki et al., 2012). The problem needs reversing, more so considering that livestock production has direct influence on food security and livelihoods in communal areas (FAO, 1992; Tessema et al., 2014). Without a permanent solution, livestock production in the regions will decrease and animal off-take from rangelands will remain low (Shackleton and Gambiza, 2008). Over time there will be food insecurity and compromised livelihoods, demand for animal products and by-products will rise continuously while animal production remains stagnant (Solanki and Naik, 1998; Thornton and Gerber, 2010).

3.2 Seed dispersion/ reseeding

Part of the solution to perennial feed shortages and rangeland degradation lies in building resilience and raising productivity of semi-arid rangelands, through manual seed dispersion/ reseeding (Saunders et al, 1993; Scholz, 1995). While nature facilitates regeneration and persistence of plant species (Saatkamp et al., 2014) the process is generally slow, and the land rarely recovers fully (Ash et al, 2011). Therefore, the onus rests on rangeland scientists, users and other interested parties to revegetate degraded rangelands and resuscitate their vigour (Saunders et al, 1993; Vandvik et al., 2016). The extensive degradation on semi-arid communal rangelands, shows lack of intervention strategies (Yates et al., 2020; Young et al., 2013) despite their necessity. Rejuvenating rangelands guarantees food and water security to humans (de Groot et al., 1992; Derner et al., 2017) and enhance biodiversity (Elridge et al., 2016), to enable rangelands to continue feeding animals (Galvin et al., 2002; Gillson et al., 2019). Degraded land is not only unproductive but fails to feed animals (Higginbottom and Symeonakis, 2014; Hobbs et al., 2008; Ibanez et al., 2007; Kassahun et al., 2008b) which impacts on food security. Therefore, the effort to buttress food security in semi-arid communal areas, must start with rangeland rebuilding through reseeding (Kiss et al., 2018; Kimiti et al., 2017). Successful reseeding has many benefits on rangelands (Mussa et al., 2016; Norton et al., 2013; Petermann and Buzhdygan, 2021). The most notable benefits of reseeding include plant species diversity, cover, improved ecosystems and increased rangeland productivity which all promote sustainability of livestock production.

3.2.1 Objectives of the study

The main objective was to study the effect of manual/mechanical seed dispersion on degraded semi-arid communal rangeland

Specific objectives were to:

- Determine the effect of different reseeding densities on the restoration of degraded semi-arid communal rangeland

- Measure species diversity and frequencies on a restored semi-arid communal rangeland
- Assess biomass production on a rejuvenated semi-arid communal rangeland
- Quantify the forage value of grass species of a restored semi-arid communal rangeland

3.3 Materials and methods

3.3.1 **Study site**

The study was conducted at Pelele Village, Ward 12, (21^0 30' S 28^0 30' E) 60 km south west of Gwanda town in Matabeleland South Province. The village has three lines; Likakeng, Mbirwane and Nyikanyoro, and 160 households distributed among the three lines. Communal farmers in the area, practiced a crop-livestock system of agriculture, however, livestock production was the better agricultural option because the site was in a semi-arid region. Livestock in the area included; 500 cattle, 300 donkeys, 600 goats and 250 sheep, which grazed on communal rangelands. Grazing space was steadily declining due to fragmentation caused by high demand for cropping land (Senda et al, 2020). The study site had 169ha fenced off to exclude grazing. However, farmers sometimes sneaked their animals into the exclosure at night to graze on the new good grass inside. This way of behaviour threatened the success of restoration but fortunately, community leaders used to conduct awareness campaigns to educate the culprits to stop the bad habit so that the rangeland would fully recover.

The site was located in agro-ecological region (AER) V, characterized by low and highly variable rainfall with an annual mean below 450mm. The rainy season usually commenced in November and tailed off in March. The soils were sandy loams. Dominant tree species were *Vachellia tortilis*, *Terminalia randii*, *Dichrostachys cineria*, *Lonchocarpus capassa*, *Combretum apiculatum*, *Cassia abbreviatta*, *Gymnosporia senegalensis*, *Colophospermum mopane*, *Grewia flavescens*, *Grewia monticola*, and *Gardenia volkenzii*. The dominant grass species were *Aristida barbicollis*, *Brachiaria deflexa*, *Chloris virgata*, *Eragrostis viscosa*, *Panicum novermnerve*, *Schmidtia pappophoroides* and *Tragus berteronianus* and forbs included *Apium leptophylum*, *Borrreria scabra*, *Ipomoea alba*, and nutsedges *Fimbristylis disticha* and *Cyperus angolensis*. There was one invasive cactus species *Cylindriopuntia fulgida* which was a threat to both the rangeland and livestock.

3.3.2 **Experimental design**

Table 3.1 Treatments in the experiment

Treatment	Activities
1	Seed + Ridges + Brushwood cover
2	Seed + Ridges
3	Seed + Brushwood cover
Control	No treatment

The trial was a (RCBD) with six 6m * 6m plots marked in each of the three blocks. There were three treatments, replicated three times (Table 3.1)

Treatment 1: Seed + Ridge + Brushwood cover (SRB)

Plots, 6m * 6m, were randomly marked in a block and replicated three times, the sixth plot was a control. After marking each plot, three ridges 15cm deep, 15cm wide and 6m long were dug in each plot at stipulated intervals using a hand-hoe. The ridges were dug across the slope and the soil mount put in the direction of the slope. The ridges harvested water, to irrigate the plots. When the ridges were ready, seeds of ten different grass species mixed together were broadcasted on plots in the different treatments, the soil was disturbed a little to cover the seeds. The grass species included; *Heteropogon contortus*, *Panicum maximum*, *Urochloa mosambicensis*, *Urochloa panicoides*, *Eragrostis superba*, *Eragrostis rigidior*, *Eragrostis trichophora*, *Digitaria eriantha*, *Chloris virgata* and *Melinis nerviglume*. Only 7g of seed for each grass species was used. Brushwood cover of *Vachellia* bushes was used to cover the plots lightly to limit grazing on the new grass seedlings. Choice of grass species broadcasted, was based on the species that were identified during a species inventory conducted prior to restoration. Information about former plant species was captured from the Free Listing Method (FLM) during a focal group discussion (FGD).

Treatment 2: Seed + Ridges (SR)

Plots, 6m * 6m were randomly marked, replicated as in the first treatment and three ridges 15cm deep, 15cm wide and 6m long were dug at stipulated intervals on each plot to harvest water.

The sixth plot was marked as a control. Seven (7g) of seeds of each of the ten species. were broadcasted on each of the five plots, the soil was disturbed a little to cover the seeds.

Treatment 3: Seed + Brushwood cover (SB)

Plots, 6m * 6m were randomly marked and replicated three times and a sixth plot was a control. Seeds of ten different grass species were mixed together, seeds of each species weighed 7g. The mixed seeds were broadcasted on each of the five plots, and the soil was disturbed a little to cover the seeds. Brushwood cover was laid on the plots to prevent limit grazing on seedlings, and allow them to grow, mature and seed so as to replenish the soil-seed bank.

The total number of treatment and control plots was eighteen (Figure 3.1). The plots were randomly distributed in three blocks marked; A, B and C. Each block had six plots which included five treatments and a control and abbreviations were used to identify each plot:

SRB – Seeds + Ridges + Brushwood

SR – Seeds + Ridges

SB – Seeds + Brushwood

CO1 – Control 1

CO2 – Control 2

CO3 – Control 3

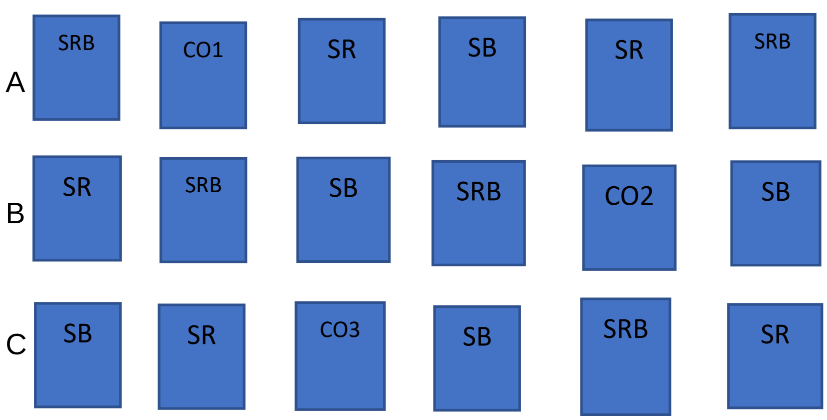


Figure 3.1: Layout of experimental plots

3.3.3 **Measurements**

Seedling counts

A quadrat (1.0m x 0.5m) was randomly laid four times in each plot and all grass and forbs seedlings were counted three days after germination.

3.2.2 Species diversity and biomass assessments

A quadrat (1.0m x 0.5m) was randomly laid six times in each plot, all species in the quadrat were identified first and recorded. All grass and forbs species were harvested with a grass clipper, put in labelled khaki sample bags and taken to a sample room. A combination of the dry-weight rank (DWR) method (Mannetjie and Haydock, 1963) and the SWIFTSYND methodology (Day et al, 1997) was used for sampling. SWIFTSYND methodology was developed in Australia in 1997, to calibrate grass production using a few samples, but still getting credible results. The harvested samples were put in a dehydrator which was run for 48 hours at 60^{0}C. After 48 hours the samples were taken out of the dehydrator and allowed to cool off, and weighed on an electronic balance in grams.

3.3.4 **Data analysis**

Statistical model and procedure

All graphical presentations were done using Microsoft Excel and statistical analyses were conducted using the General Statistical Software (Genstat) 14^{th} Edition (2017). The Statistical Package for Social Scientists (SPSS, IBM version 21) was used to compute data on species frequencies. Data were tested for normality assumptions before being subjected to the analysis using the Shapiro-Wilk test. Biomass productivity across all treatments was analyzed in a one-way ANOVA with biomass as the response. A general Linear Model (GLM) was fitted to test the effect of treatments on biomass production (t/ha) in Genstat. Treatments were specified as a factor and biomass productivity as response variables. Differences of means between treatments were tested using a Least Significant Difference (LSD) post hoc test at 5% level of significance. Treatment for the j^{th}

A General Linear Model (GLM) of the form (eq(1) below was fitted to the biomass productivity data

$Y_{ij} = \mu + Ʈ_i + Є_{ij}$ eq(1)

Where Y_{ij} was the amount of biomass observed in the i^{th} treatment for the j^{th} plot (Control, SR, SB SRB)

$Ʈ_i$ the i^{th} treatment effect on the observed biomass

$Є_{ij}$ was the error term

μ was the overall estimate of the population mean

3.4 RESULTS

3.4.1 **Seedling counts**

Seedlings of grass species were significantly higher ($p < 0.01$) than those of forbs species in two treatments; Seed + Ridges and Seed + Ridges + Brushwood and very low in the Seed + Brushwood (Table 3.2). Seedlings of forbs were high in the Seed + Brushwood treatment and lower in the other treatments. The combined effect of ridges reduced runoff and increased infiltration and brushwood cover which provided protection to the seedlings was responsible for the high seedling populations in the two treatments. The control plot had lower populations of seedlings for both grass and forbs species, an indication that the soil seed bank was very depleted. Reseeding showed that it was an effective way of replenishing the soil seed bank, hence it is suitable for rebuilding degraded rangelands successfully.

Reseeding has significant effect in rejuvenating degraded rangelands, it allows the operator to select the ideal species of grass to introduce on a given site. As such, perennial grass species which often go extinct following heavy utilization resulting in degradation, can be re-introduced on a degraded site. Stability of habitats and ecosystems can be achieved successfully through reseeding. (Figure 3.2) shows observed seedling counts per square metre, indicating higher seedling densities for grass species across treatments.

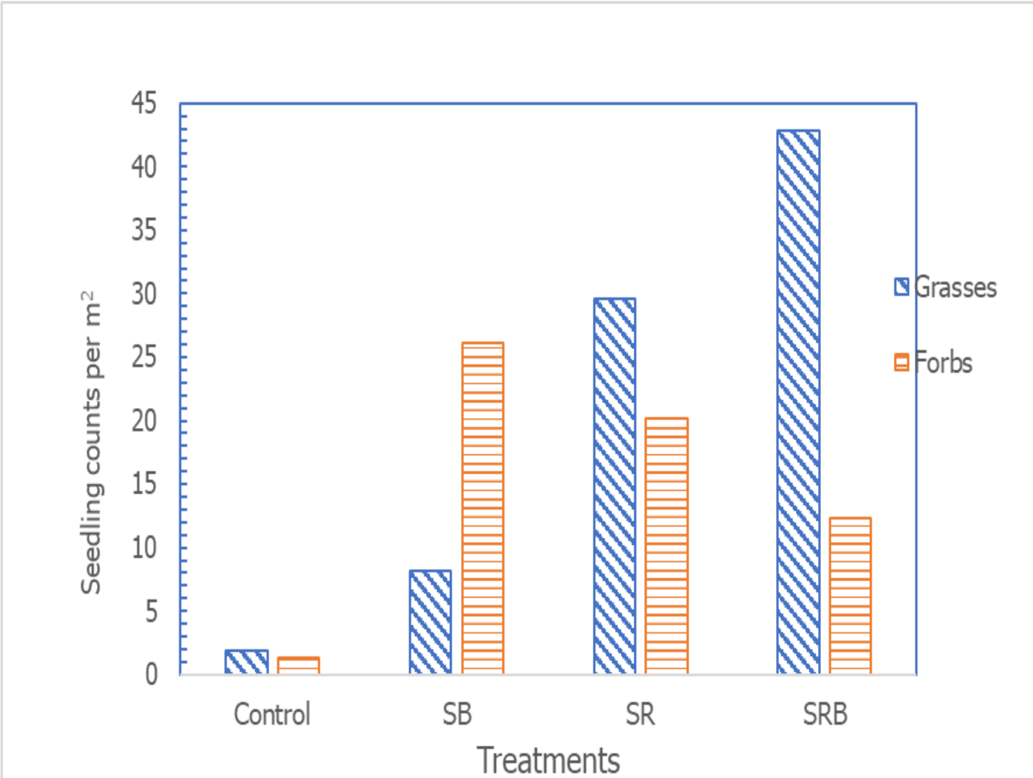


Figure 3.2: **Seedlings of grasses and forbs counted in the different treatments**

Semi-arid communal rangelands have been extensively degraded which further complicates rangeland productivity. Intervention strategies such as reseeding can reverse the degradation and rejuvenate rangelands, which in the long term will increase biomass production and reduce feed shortages. (Figure 3.3), indicates extrapolated seedling densities on a larger scale and the numbers of thousands of grass seedlings counted per hectare. Take for instance, if a hectare in the semi-arid communal rangelands is reseeded, and the treatment is Seeds + Ridges + Brushwood the expected seedling density would be four hundred and sixty thousand (460 000) grass seedlings. Such a high number of new seedlings makes a significant impact on the rangeland's species diversity and biomass production.

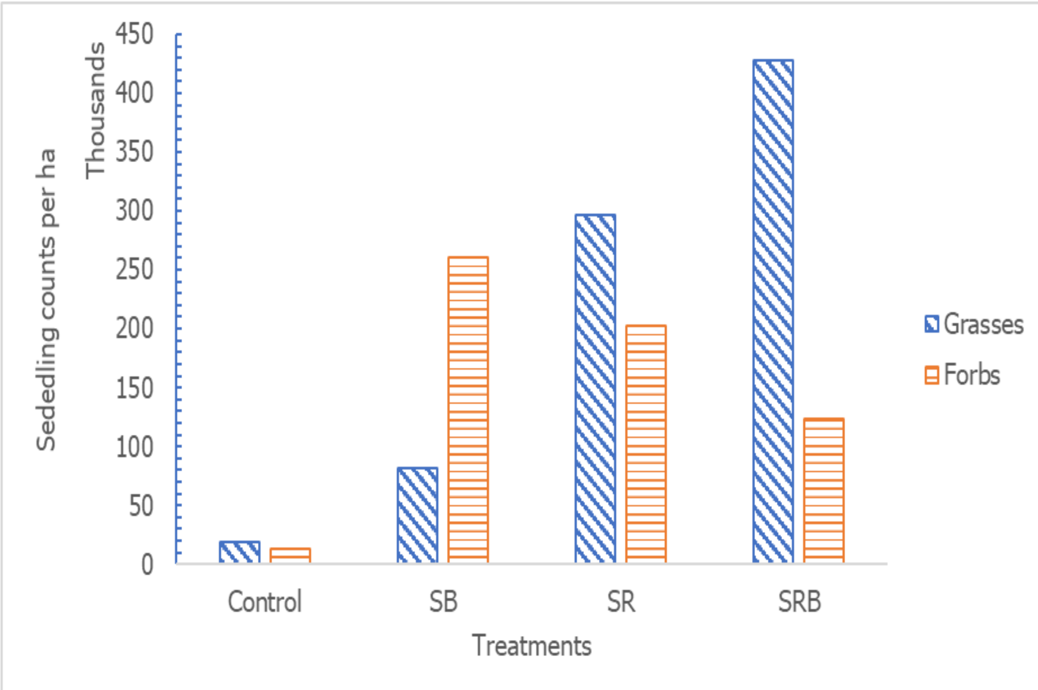


Figure 3.3: Seedlings of grasses and forbs in the different treatments expressed per hectare

3.4.2 Reseeding

Reseeding increased species diversity (Table 3.2) in the treatment with Seed + Ridges + Brushwood (SRB), where seven introduced perennial grass species; *Heteropogon contortus* 13.8%, *Schmidtia pappophoroides* 12.1%, *Urochloa mosambicensis* 11.5%, *Eragrostis trichophora* 9.8%, *Eragrostis rigidior* 6.9%, *Panicum maximum* 6.3% and *Eragrostis superba* 0.6% were observed. The seven species had good forage value in addition to producing big culms and leaves which translates to more biomass. There was one unpalatable perennial grass species *Melinis nerviglume* 0.6% that was introduced in the treatment. There was one annual grass species with good forage value; *Chloris virgata* 8.6% while the other four had poor forage value; *Aristida barbicollis* 10.9%, *Eragrostis* species 3.4%, *Eragrostis viscosa* 3.4% and *Tragus berteronianus* 2.9%. There was great improvement in the species diversity and the forage value of grass species, an indication that reseeding improves species diversity on rangelands. Observed forbs species which contributed a proportion of 5.7% had poor forage value. In the (SRB) treatment *Heteropogon contortus* was the dominant grass species.

Table 3.2: Frequencies of grass species at Seeds + Ridges + Brushwood (SRB) treatment

Treatment	Species	Number of species observed	Proportion (%)
SRB	Hc^{*P}	24	13.8%
	Spa^{*P}	21	12.1%
	Um^{*P}	20	11.5%
	Ab^{UA}	1	10.9%
	Et^{*P}	17	9.8%
	Cv^{*A}	15	8.6%
	Er^{*P}	12	6.9%
	Pm^{*P}	11	6.3%
	Fb^{UA}	10	5.7%
	De^{*P}	6	3.4%
	Esp^{UA}	6	3.4%
	Ev^{UA}	6	3.4%
	Tb^{UA}	5	2.9%
	Es^{*P}	1	0.6%
	Mn^{UP}	1	0.6%

Table 3.3: Frequencies of grass species at Seeds + Brushwood (SB) treatment

Treatment	Species	Number of species observed	Proportion (%)
SB	Hc^{*P}	15	19.7%
	Um^{*P}	14	18.4%
	Ab^{UA}	14	18.4%
	Et^{*P}	6	7.9%
	Cv^{*A}	6	7.9%
	Er^{*P}	5	6.6%
	Pm^{*P}	5	6.6%
	Fb^{UA}	3	3.9%
	De^{*P}	3	3.9%
	Esp^{UA}	2	2.6%
	Tb^{UA}	2	2.6%
	Es^{*P}	1	1.3%

Grass species in treatment; Seeds + Brushwood (SB) (Table 3.2) were dominated by *Heteropogon contortus* a palatable perennial grass species which had a proportion of 19.7%. Other palatable perennial grass species that were introduced through reseeding include; *Urochloa mosambicensis* 18.4%, *Eragrostis trichophora* 7.9%, *Eragrostis rigidior* 6.6%, *Urochloa mosambicensis* 6.6%, *Panicum maximum* 6.6%, *Digitaria eriantha* 3.9% and *Eragrostis superba* 1.3% with a total of eight perennial grass species with good forage value. Annuals had one palatable species; *Chloris virgata* with a proportion of 7.9% and three unpalatable species; *Aristida barbicollis* 18.4%, *Eragrostis* species 2.6% and *Tragus berteronianus* 2.6%. Observed forbs were not palatable.

Table 3.4: Frequencies of grass species at Seeds + Ridges (SR) treatment

Treatment	Species	Number of species observed	Proportion (%)
SR	Hc^{*P}	24	15.0%
	Um^{*P}	20	12.5%
	Ab^{UA}	19	11.9%
	Et^{*P}	17	10.6%
	Cv^{*A}	15	9.4%
	Er^{*P}	15	9.4%
	Pm^{*P}	15	9.4%
	Fb^{UA}	13	8.1%
	De^{*P}	11	6.9%
	Esp^{UA}	4	2.5%
	Tb^{UA}	4	2.5%

Table 3.2. indicates that reseeding resulted in six palatable perennial grass species; *Heteropogon contortus* 15.0%, *Urochloa mosambicensis* 12,5%, *Eragrostis trichophora* 10.6%, *Eragrostis rigidior* 9.4%, *Panicum maximum* 9.4% and *Digitaria eriantha* 6.9%. No unpalatable perennial grass species was observed in this treatment. There were four annual grass species, out of these only one was palatable; *Chloris virgata* 9.4%; while the other three; *Aristida barbicollis* 11.9%, *Eragrostis* species 2.5% and *Tragus berteronianus* 2.5% were not palatable. Observed forbs were also not palatable.

Table 3.5: Frequencies of grass species at Control plot

Treatment	Species	Number of species observed	Proportion (%)
Control	Um^{*P}	19	31.7%
	Ab^{UA}	13	21.7%
	Fb^{UA}	12	20.0%
	Esp^{UA}	11	18.3%
	Tb^{UA}	2	3.3%
	Bd^{UA}	2	3.3%

The number of palatable perennial grass species in the Control plot was low (Table 3.5) only one species; *Urochloa mosambicensis* contributing a proportion of 31.7% was observed. There were no palatable annual grass species observed except for four unpalatable ones; *Aristida barbicollis* 21.7%, *Eragrostis* species 18.3%, *Tragus berteronianus* 3.3% and *Brachiaria deflexa* 3.3%. The observed forbs species were not palatable.

Note: The key below must be read with Tables 3.1 to 3.4 and Figures 3.2 and 3.3

Key

Ab^{UA}	*Aristida barbicollis* (^{UA} unpalatable annual)
Cv^{*A}	*Chloris virgata* (^{*A} palatable annual)
De^{*P}	*Digitaria eriantha* (^{*P} palatable perennial)
Er^{*P}	*Eragrostis rigidior* (^{*P} palatable perennial)
Esp^{UA}	*Eragrostis* species (^{UA} unpalatable annual)
Es^{*P}	*Eragrostis superba* (^{*P} palatable perennial)
Et^{*P}	*Eragrostis trichophora* (^{*P} palatable perennial)
Ev^{UA}	*Eragrostis viscosa* (^{UA} unpalatable annual)
Forb^{UA}	Forb species (^{UA} unpalatable annual)

Hc*P	*Heteropogon contortus* (*P palatable perennial)
MnUP	*Melinis nerviglume* (UP unpalatable perennial)
Pm*P	*Panicum maximum* (*P palatable perennial)
Spa*P	*Schmidtia pappophoroides* (*P palatable perennial)
Um*P	*Urochloa mosambicensis* (*P palatable perennial)
TbUA	*Tragus berteronianus* (UA unpalatable annual)
SB	Seeds + Brushwood
SR	Seeds + Ridges
SRB	Seeds + Ridges + Brushwood

3.4.3 **Plant species biodiversity**

There was multi-species mix of plants observed, following reseeding in the different treatments (Figure 3.2), which in the long run will improve fodder availability to livestock as well as build resilience and productivity of the rangeland. Introducing grass species by reseeding increased the number of grass species on treatments, which composed both annual and perennial grass species. While this is important in the plant communities, it is equally necessary for the good of ecosystems. *Aristida barbicollis* was dominant on the site prior to the intervention however, this changed and *Heteropogon contortus* became the dominant grass species following its introduction into the treatments.

3.4.4 **Effect of treatment on reseeding**

Treatment significantly affected reseeding as indicated by the results; Seeds + Ridges + Brushwood (SRB) had the highest number of grass species, both perennial and annual. Ridges contributed to the good result by helping water to infiltrate into the soil and irrigate the reseeded areas and enhanced higher seedling germination. In addition, brushwood cover provided protection to the new grass seedlings against grazers, hence the large number of grass species (15 species) (Table 3.2). The trend persisted across the rest of the treatments; Seeds + Brushwood (SB) 12 species, Seeds + Ridges (SR) 11 species while the Control plot had 6 species. Reseeding showed a great potential of rejuvenating semi-arid communal rangelands which have been badly degraded.

Seed + Ridges + Brushwood SRB)

Fifteen (15) grass species were identified on the treatment *Heteropogon contortus*, *Schmidtia pappophoroides*, *Urochloa mosambicensis*, *Aristida barbicollis*, *Eragrostis trichophora*, *Chloris virgata*, *Eragrostis rigidior*, *Panicum maximum,* Forbs, *Digitaria eriantha*, *Eragrostis* species, *Eragrostis viscosa*, *Tragus berteronianus*, *Eragrostis superba* and *Melinis nerviglume* (Gibbs Russell et al, 1991). Out of the grass species, nine of them; *Heteropogon controtus*, *Schmidtia pappophoroides*, *Urochloa mosambicensis*, *Eragrostis trichophora*, *Eragrostis rigidior*, *Panicum maximum*, *Digitaria eriantha*, *Eragrostis superba* and *Melinis. nerviglume* were perennial species (Chippindall and Cook, 1976). In terms of forage value, eight of the species were good, only one grass species had no forage value (Table 3.2). There was one palatable annual grass species (*Chloris virgata*), four annual grass species had no forage value; *Eragrostis viscosa*, *Tragus berteronianus*, *Aristida barbicollis* and *Eragrostis* species as well as one unpalatable species of forbs.

Seed + Brushwood (SB)

Results of the species inventory showed that there were twelve species (eleven grass species and one forb species) *Heteropogon contortus*, *Urochloa mosambicensis*, *Aristida barbicollis*, *Eragrostis trichophora*, *Chloris*.*virgata*, *Eragrostis rigidior*, *Panicum maximum*, Forbs, *Digitaria eriantha*, *Eragrostis* species, *Tragus* b*erteronianus* and *Eragrostis superba*. Out of the eleven grass species identified, seven were perennial grass species, four were annual grass species and one was a forb species. In terms of the forage value of the grass species; the seven perennial grass species were palatable; *Heteropogon contortus*, *Urochloa mosambicensis*, *Eragrostis rigidior*, *Panicum maximum*, *Digitaria eriantha* and *Eragrostis superba*. There was one palatable annual grass species *Chloris virgata*, three unpalatable annual grass species; *Aristida barbicollis*, *Eragrostis* species, *Tragus berteronianus* and one unpalatable forbs species.

Seed + Ridges (SR)

Ten (10) grass species; *Heteropogon contortus*, *Urochloa mosambicensis*, *Aristida barbicollis*, *Eragrostis trichophora*, *Chloris virgata*, *Eragrostis rigidior*, *Panicum maximum*, *Digitaria eriantha*, *Eragrostis* species, *Tragus berteronianus* and a forbs species were identified on the treatment. Out of the grass species identified, six were palatable perennial grass species, one annual grass species was palatable, three annual grass species and one forb species were unpalatable.

Control

Results of an inventory of species showed five (5) grass species; *Urochloa mosambicensis*, *Aristida barbicollis*, *Eragrostis* species, *Tragus berteronianus*, *Brachiaria deflexa* and a forbs species. Out of the species, only one perennial grass species *Urochloa mosambicensis* was palatable, while four annual grass species were unpalatable; *Aristida barbicollis*, *Eragrostis* species, *Tragus berteronianus* and *Brachiaria deflexa.* There was one unpalatable annual forbs species.

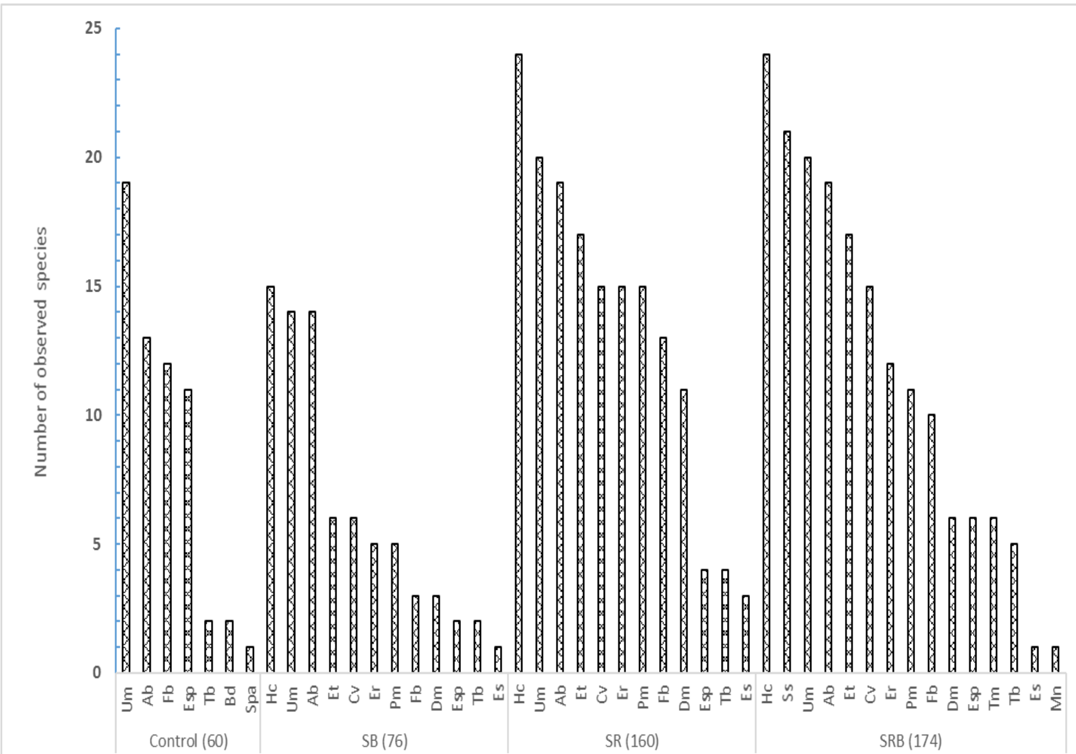


Figure 3.4: Grass species observed at treatments following reseeding

Reseeding induced high biodiversity of grass species (Figure 3.4) across treatments. In the Seeds + Ridges + Brushwood (SRB) 15 species were observed, Seeds + Brushwood (SB) 12 species were observed and Seeds + Ridges (SR) 12 species were observed. The Control had 7 species. The species included annuals and perennials, some of which were palatable while others were unpalatable. What is coming out clearly is that reseeding resulted in a huge increase in species. This implies that in order to increase species biodiversity on semi-arid communal rangelands, reseeding does a good job. Semi-arid communal rangelands have been over grazed and became degraded, common species observed include annuals which apart from producing low biomass are also unpalatable. This makes the species unsuitable for livestock production, yet semi-arid communal rangelands are famous for supporting the agricultural activity.

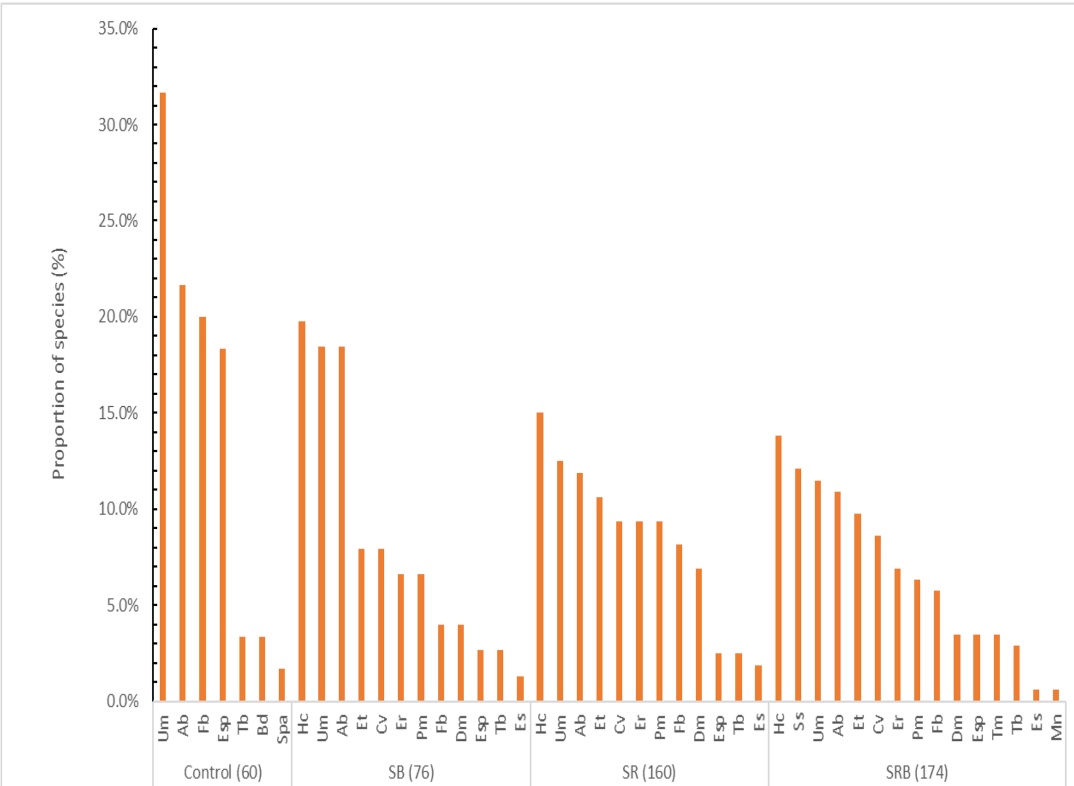


Figure 3.5: Proportions of grass species observed in the different treatments

Key

SB	Seed + Brushwood
SR	Seed + Ridges
SRB	Seed + Ridges + Brushwood

One of the benefits of reseeding is enhancement of species biodiversity on rangelands (Figure 3.5). Following reseeding, species observed at treatments contributed significant proportions to the herbaceous species, for instance *Heteropogon contortus* contributed 15% at Seeds + Ridges (SR). The trend is the same in the other treatments, proportions of grass species were high, indicating that reseeding is a suitable intervention to be used in semi-arid communal areas to reverse degradation and increase species biodiversity. It is known that communal rangelands are seriously degraded, which has compromised the rangelands' ability to provide adequate fodder to grazers.

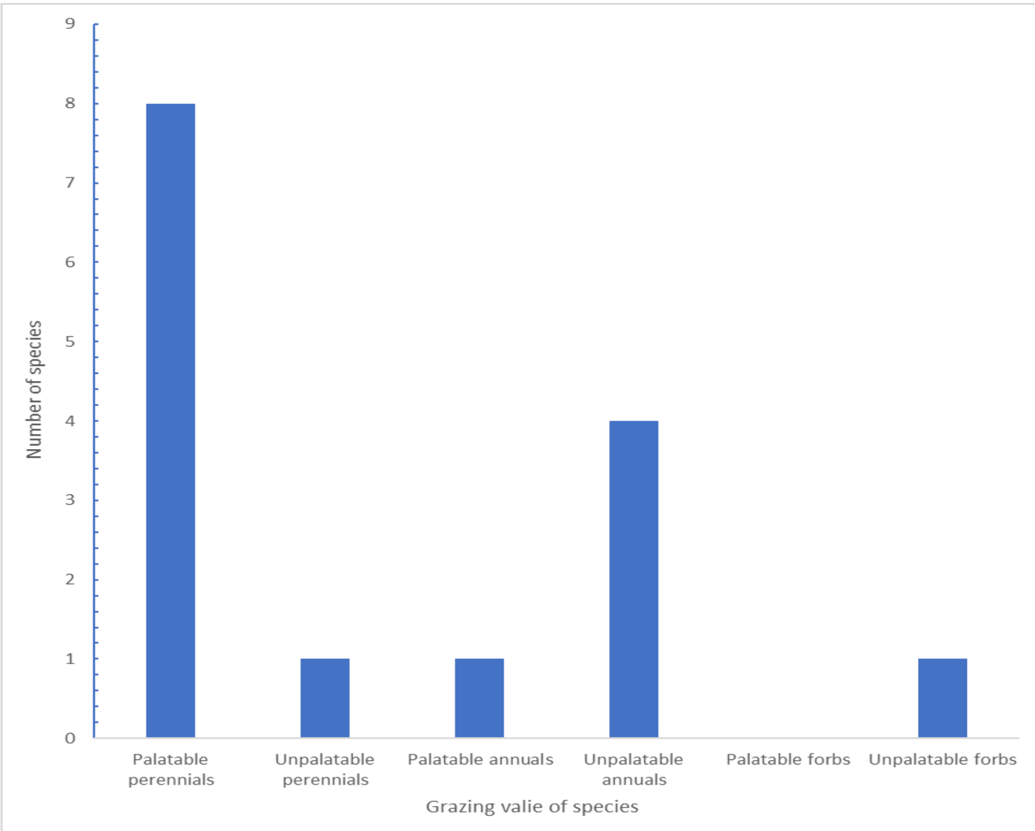


Figure 3.6: Numbers of different plant species grouped according to grazing value

There were seven perennial grass species (Table 3.6) that were palatable in the treatment with Seeds + Ridges + Brushwood (SRB). One annual grass species was also palatable, but there were three unpalatable annual grass species. Forbs species had one unpalatable species. Palatability of the grass species was determined through the use of a book by written by Chippindall and Cook (1976) which indicates grass species that have good grazing value and those that do not have good grazing value. Reseeding used with ridges and brushwood increased species biodiversity and forage value. This shows that that semi-arid communal rangelands can be restored using seeds, ridges and brushwood cover.

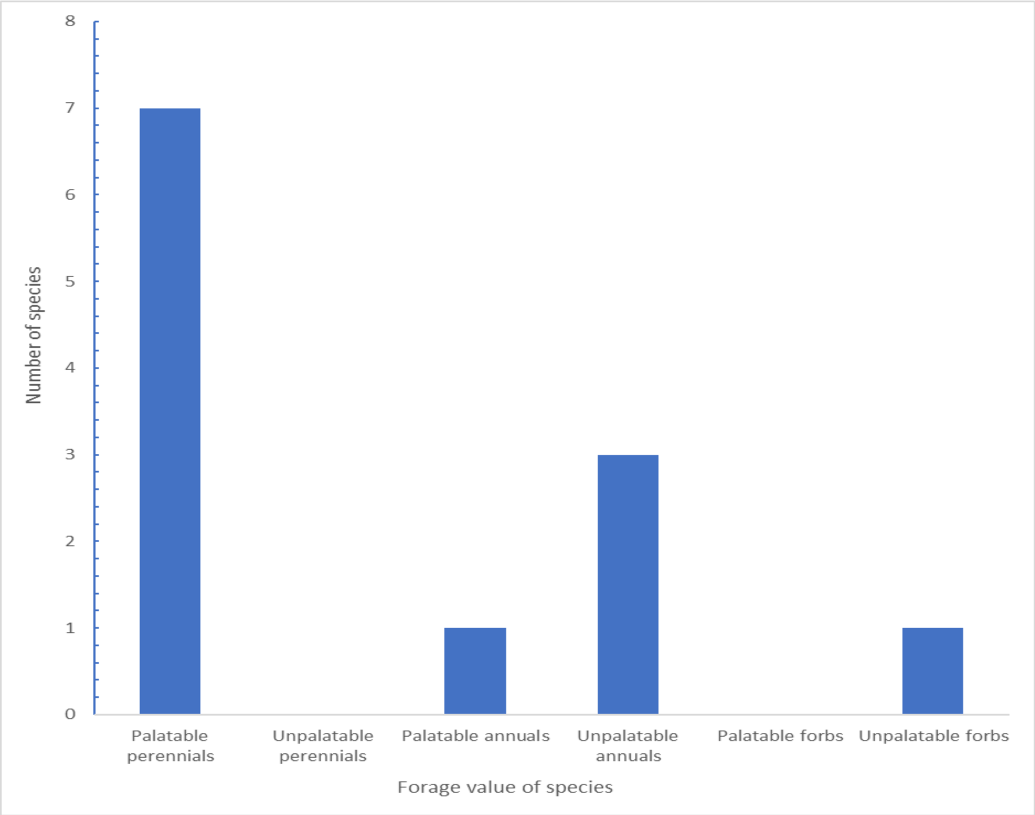


Figure 3.7: Numbers of different plant species grouped according to grazing value at Seeds + Brushwood

Treatment; Seeds + Brushwood (SB) (Figure 3.7) showed that seven perennial grass species observed in the treatment were palatable. One annual grass species was also palatable however, the number of unpalatable annual grass species was more (three) while forbs species only had one unpalatable species. What this indicates is that reseeding can be used on degraded rangeland to perform two functions: (i) Increasing species biodiversity and (ii) Increasing the number species with good grazing value. Considering that semi-arid communal rangelands are severely degraded the methodology looks suitable for reversing the degradation.

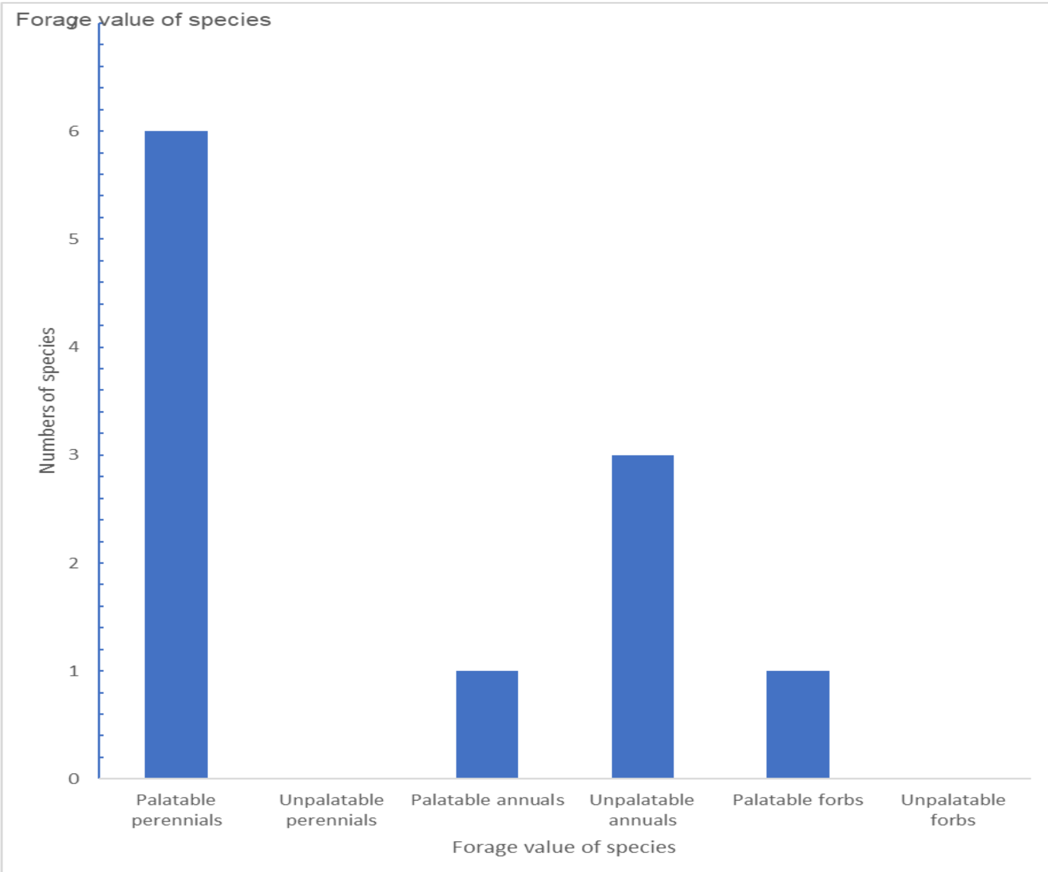


Figure 3.8: Numbers of different plant species grouped according to grazing value in the Seeds + Ridges treatment

Reseeding is a reliable method of rebuilding a degraded rangeland (Figure 3.8) indicates six perennial grass species which were introduced on a degraded and increased the number of palatable species. While the numbers of palatable annual grass species and forbs was one for each, there were three unpalatable annual grass species. The advantage of having more perennial grass species on rangelands is that they produce more biomass and also do not depend on seeds for perpetuation. New shoots come out every season making perennial grass species more important on the rangeland.

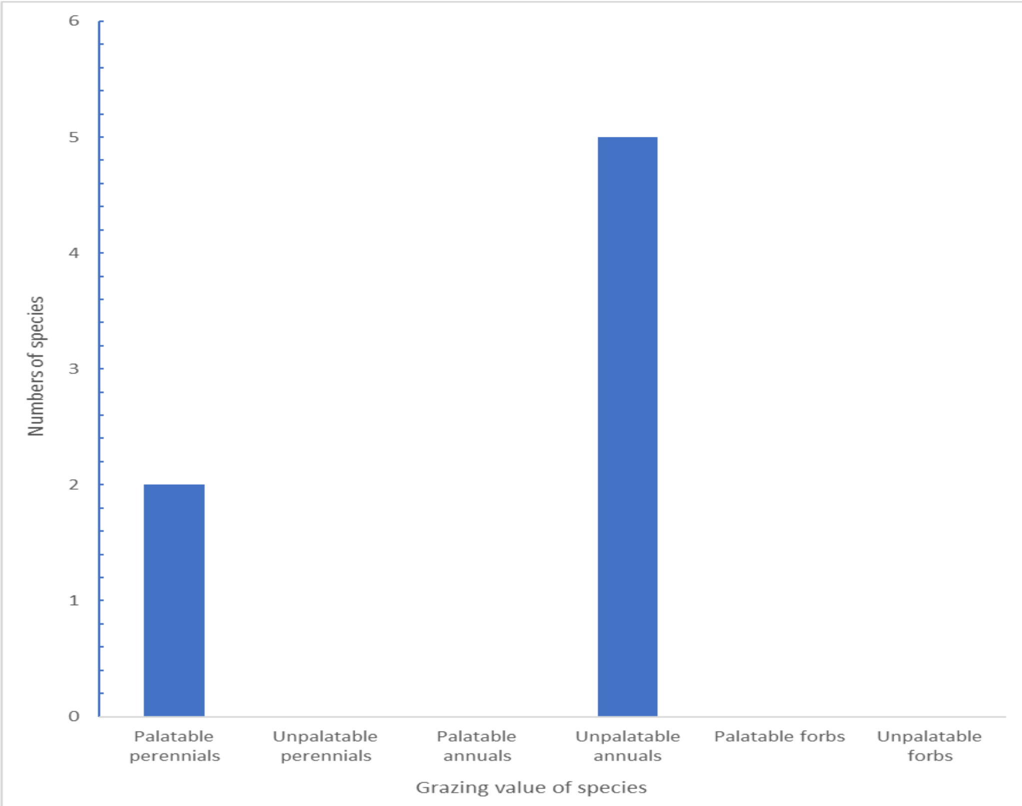


Figure 3.9: Numbers of different plant species grouped according to grazing value in the Control

Treatment had an effect on species diversity as indicated in (Figure 3.9) which was not treated. There were fewer perennial grass species in the Control plot which reflects of the degree of degradation on the rangeland. There were only two palatable perennial grass species, while unpalatable annual grass species were five. A degraded rangeland is usually populated by annual species which apart from producing low biomass, are not palatable.

3.4.5 Assessment of biomass production

Results of the experiment showed that reseeding increased biomass production across treatments (Table 3.3 and Figure 3.9) Ridges and brushwood cover had an effect on treatments; ridges increased infiltration and it resulted in the germination of more grass seedlings, while brushwood cover protected the seedlings from heavy grazing, thereby giving them chance to grow and produce biomass. Treatment also significantly affected the amount of biomass observed after different treatments of reseeding were used ($p < 0.01$; SED = 0.0399). Production of biomass tripled on treatments at Seeds + Ridges + Brushwood (SRB) while it doubled at Seeds + Ridges (SR) and brushwood used independently with treatments resulted in the production of more biomass.

The increased number of perennial grass species that were introduced on the treatments caused a rise in biomass production, a factor that can be attributed to their large culms and leaves.

Table 3.6: Biomass production measured at different treatments

Treatment	Yield (t/ha)	Std Dev.
Control	0.079^{c}	0.030
Seeds + Brushwood	0.254^{ab}	0.167
Seeds + Ridges	0.204^{b}	0.120
Seeds + Ridges + Brushwood	0.285^{a}	0.160

^{a,b} means with different letter superscripts were significantly different at 5% level of significance

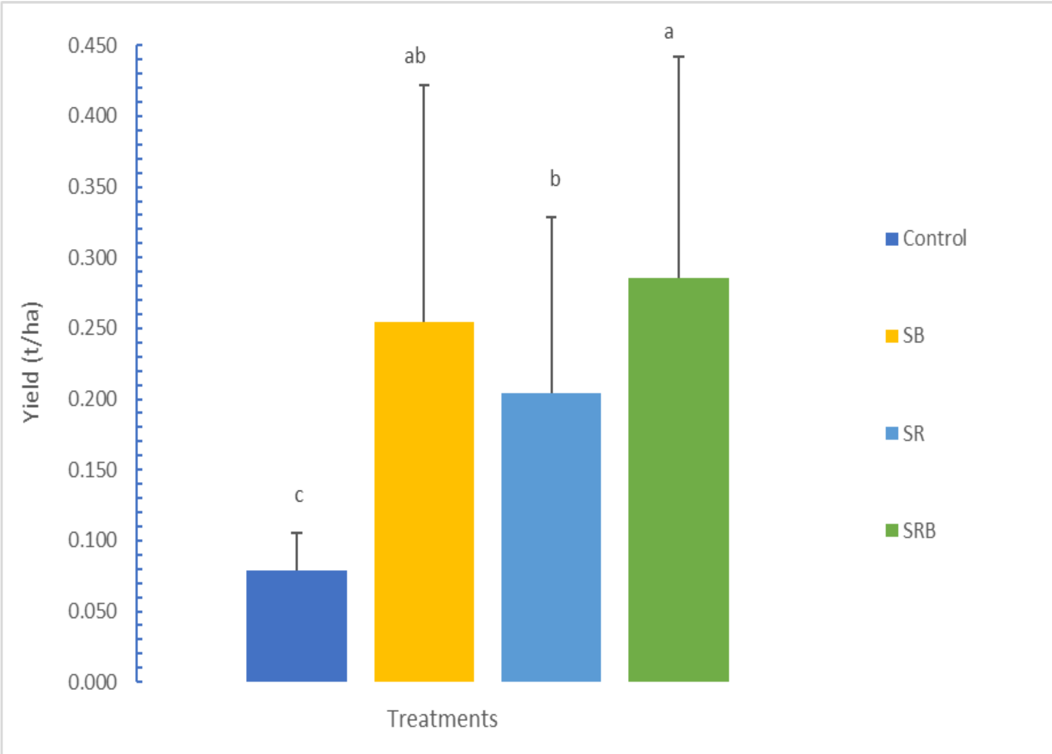


Figure 3.10 Graph showing biomass production in the different treatments

[a,b] means with different letter superscripts were significantly different at 5% level of significance

Treatment shows that it had an effect on biomass production (Figure 3.10) as shown by letters a, b in superscripts. Biomass production trebled at treatment Seeds + Ridges + Brushwood, while it doubled at Seeds + Brushwood. Reseeding used with other treatments such as ridges and brushwood raised biomass production at treatments.

3.5 Discussion

3.5.1 Seedling densities

The significantly higher seedling densities at treatments (Figure 3.5) indicates that germination of grass seedlings on a rangeland, is influenced by a healthy soil seed bank (Fenner and Thompson, 2005; Shi et al., 2020). Species perpetuation, persistence, and vigour are factors which are heavily dependent on the health of soil seed banks (Karubian and Duraes, 2009; Gioria et al., 2012), although other auxiliary factors both biotic and abiotic influence rangeland stability (Izzauralde et al., 2011; Abdelsalam et al., 2017). It has been suggested that one of the probable drivers of reduced rangeland vigour is poor management (Liu et al., 2009; Kgosikoma et al., 2015), which results in over utilization and subsequent degradation (Olff and Ritchie, 1998; Mussa et al., 2016), hence poor soil seed bank replenishment (Bo et al., 2013). The decline in seedling populations of both grass and forbs species in the control plot (Figure 3.5) indicated that several years of over utilization, influenced depletion in soil seed banks of semi-arid communal rangelands' (Rutherford and Powrie, 2013; Saatkamp et al., 2014; Kiss et al., 2018).

The considerably higher densities of forb species' seedlings observed on two treatments at Seeds + Brushwood and Seeds + Ridges was not expected and requires further investigation. The soil type at both treatments is homogeneous displaying sandy loam characteristics and low fertility. The seeds of forbs could probably have been imported into the plots by seed dispersion agents such as water and wind (Chamber et al., 1994; Gioria et al., 2012). This is highly probable due to two reasons; (i) Treatment at Seeds + Brushwood, had no ridges, hence runoff was high in the plot therefore, water could have brought in seeds of the forbs species (ii) Treatment at Seed + Ridges, had no brushwood cover, making it highly probable that wind could be responsible for bringing in the seeds from the vicinity (Shang et al., 2009).

The forbs species observed in the treatments were not palatable (Table 3.1) and (Figure 3.5). While they do not serve much purpose on the rangeland, they provide protection to the soil (Long et al., 2008). Despite offering protection to the environment (Gioria et al, 2012), the forbs do not address the problem of feed shortages which are threatening sustainability of livestock production (Izzauralde et al., 2011; Thornton et al., 2015). A question then arises whether the characteristic smell produced by some the forb species is the reason why animals shunned them or whether there are particular chemical compounds responsible for the shunning. Small ruminants especially goats are natural browsers (Sebata and Ndlovu, 2011) and could have utilized the forbs. However, they too like cattle did not touch the forbs, which partly explains the high densities of forbs species (Shi et al., 2020). Palatable forbs species such as Wandering Jew (*Commelina benghalensis*) and Sabi Morning Glory (*Ipomoea plebia*) were conspicuously absent, because they were probably grazed to extinction (Cousens et al., 2010; Skalova et a., 2019). Only unpalatable species such as *Apium leptophylum* and *Borreria scabra* were observed.

3.5.2 **Frequencies of plant species introduced in the different treatments**

While species frequencies in the different treatments were high (Jaunatre et al., 2014) they were significantly higher (Figure 3.5) at Treatment; Seeds + Ridges + Brushwood (SRB) than Seeds + Brushwood (SB) and Seeds + Ridges (SR), indicating that treatment had a positive effect on species frequencies (Dahlberg, 2000). Perennial grass species frequencies were exceptionally higher and were dominated by the following species in descending order; *Heteropogon contortus*, *Urochloa mosambicensis*, *Eragrostis trichophora*, *Eragrostis rigidior*, *Panicum maximum*, *Digitaria eriantha*, *Eragrostis superba* and *Schmidtia pappophoroides* (Gibbs Russell et al., 1991; Kwembeya and Takawira, 2013). The result favours rangeland sustainability, because perennial grass species do not necessarily perpetuate by seed only, but can regrow from shoots (Snyman et al., 2013; de Groot et al., 1992).

Although frequencies of perennial grass species were higher, it was the opposite for annual grass species. There were fewer, and observed species included; *Chloris virgata, Tragus berteronianus*, *Aristida barbicollis*, *Eragrostis viscosa*, and *Eragrostis* species at all treatments (Petermann and Buzhdygan, 2021). While this could not be explained, it could have probably been influenced by the viability of annual species' seeds broadcasted on the treatments. The seeds were probably harvested much earlier than their physiological maturity, which compromised their viability (Wenny and Nyboer, 2008). Unlike perennial grass species, annuals depend entirely on seeds for perpetuation, which explains why immature grass seeds hardly germinate after planting (Alabdulla, 2019). This is one weakness of rebuilding degraded rangelands using seeds of grass species. The intervention had its own strengths and weaknesses, however, despite the shortcomings, the exercise was successful judging from the densities of perennial grass species (Saatkamp et al., 2014). Any element of doubt, must be dealt with through further investigation to enhance the drawing up of solid conclusions which could be useful for similar future work. However, proof has been availed showing that reseeding can address the pertinent issue of degradation in semi-arid communal rangelands (Gokbulak, 2006).

Of importance to remember, is that annual and perennial members of the poaceae communities play critical roles, both in the balance of ecosystems and habitats as well as the provision of animal fodder (Petermann and Buzhdygan, 2021). Their co-existence is absolutely necessary, because when one species disappears probably as a direct result of human activities, the other can take over roles meant for both of them (Rohde et al., 2006; Palmer and Bennett, 2013). During rangeland reconstruction exercises it is critical to ensure that seeds of both herbaceous community members are adequately represented (Vandvik et al., 2016). While perennial species persist on rangelands by tillers or shoots, annual species accomplish that by seeds for persistence and perpetuation (Kiss et al., 2018; Vandvik et al., 2016).

3.5.3 Diversity of plant species introduced in the different treatments

Observed grass species in the different treatments showed diversity (Figure 3.5), indicating effectiveness of the intervention (Squires et al., 2018). Results of treatments; Seeds + Ridges + Brushwood (SRB), Seeds + Brushwood (SB) and Ridges + Brushwood (RB) proved that mixing different grass seeds enhanced mixed species on rangelands (Saatkamp et al., 2014). It also showed that the broadcasted seeds were physiologically mature which influenced high germination percentages. Diversity of grass species (Scherber et al., 2010) enhances herbaceous plants' interaction with animals to persist while they are being grazed (Gibbs Russel et al., 1991; Cingolani et al., 2005). Plant species diversity also increases chances of species adaptation to the different veld types of the country (Muandani et al., 2012). The existence of the veld types streamlined grass species into two classes; mesic and xeric to enhance adaptability (Abrams et al., 1990; Elliott et al., 2014).

Grass seeds broadcasted during the reseeding exercise, fall under the xeric class of species (Abrams et al., 1990). This characteristic enables the grass species' adaptation to semi-arid climatic conditions which form the sweet veld (Squires et al., 2018). Consequently, this positions extensive livestock production from the rangelands as the better agricultural option in semi-arid areas. Grasses such as *Heteropogon contortus*, *Panicum maximum*, *Eragrostis superba*, *Digitaria eriantha*, *Eragrostis trichophora*, *Urochloa mosambicensis* and *Chloris virgata* are common species in semi-arid rangelands also known as sweet veld, which explains why they established favourably on the reseeded sites (Soder et al., 2007; Spinage, 2012; Squires et al., 2018). The species are popular in semi-arid communal rangelands because of their good forage value (Archer, 2006). Due to their prevalence on sweet veld, the grass species are the reason the veld is called sweet veld, the species are palatable throughout the year (Cayssials and Rodriguez, 2016). They are usually over utilized because animals prefer them, they are always picked first and selectively grazed, while the unpalatable ones remain untouched (Zama, 2018). However, the major limitation associated with the grass species is that their production is limited, which explains why feed shortages in semi-arid areas are frequent (Arshadullah et al., 2011).

The absence of *Hyparrhenia rufa* and *Hyparrhenia filipendula* in observed species was not by coincidence (Izzauralde et al., 2011), but very much influenced by adaptability. *Hyperrhenia rufa* and *Hyperrhenia filipendula* are mesic species (Elliott et al., 2014), hence they are mostly restricted to high rainfall areas where they form Hyparrhenia tall-veld or what is commonly referred to as sour veld (Mugandani et al., 2012). Grazing in such veld types is only good during the growing season, thereafter, palatability decreases when the grasses start to flower and worsens in the dry season due to lignification, which causes animals to shun them (Cowlishaw and Alder, 2009). In drawing up a list of grass species used for rangeland rebuilding, two factors were considered; forage value and adaptability.

3.5.4 **Assessment of biomass production at treatments**

Reseeding influenced significant increase in the amount of biomass produced on observed treatments (Table 3.6 and Figure 3.10) ($p<0.01$, S.E.D = 0.0399) (Getabalew and Alemneh, 2019). Results showed that treatment had significant effect on biomass production; SRB – 0.285t/ha, SB – 0.254t/ha and SR – 0.204t/ha. Consequently, biomass production tripled at treatment; Seed + Ridges + Brushwood (SRB) and doubled at Seed + Brushwood (SB) independently used. Use of brushwood cover on plots produced better results compared to treatment at Seed + Ridges (SR). It is probable that brushwood cover protected the grass seedlings and limited grazing hence more biomass on the treatments.

Probable factors could have influenced the significance; (i) Introduction of seeds of different grass species which increased species diversity and densities (Kiss et al., 2018; Getabalew and Alemneh, 2019) (ii) Ridges harvested water and provided more moisture to the grass seedlings and (iii) Brushwood cover offered protection against grazing to the grass seedlings. All species introduced on the sites; *Panicum maximum*, *Eragrostis superba*, *Digitaria eriantha, Heteropogon contortus* and the other species are perennials known for producing large culms and leaves resulting in unusual leafiness and bulky biomass, making them more suitable species for livestock production (Manske, 2005). However, results of the Control plot showed the opposite, most grass species on it were annuals; *Aristids barbicollis*, *Eragrostis* species, *Tragus berteronianus* and *Brachiaria deflexa* which apart from being unpalatable produce little biomass hence they cannot support livestock production (Gioria et al., 2012). The positive results on treatments provide empirical evidence that semi-arid communal rangelands which have been constrained by serious degradation for many years, can be rejuvenated with grass species adapted to sweet veld (Alabdulla, 2019; Cousens et al., 2010; de Groot et al., 1992).

A question arises whether rangeland mismanagement is the only cause of low rangeland productivity or whether other factors are responsible for the anomaly in semi-arid communal rangelands (Buzhdygan et al., 2020; Petermann and Buzhdygan, 2021). Utilization in semi-arid communal rangelands is very heavy, negatively affecting plant species diversity and productivity (Deng et al., 2013). Other extenuating factors include rangeland fragmentation (Senda et al., 2020) due to high demand for cropping land (Hlatshwayo, 2017), over population (Rutherford and Powrie, 2013; Sasaki et al., 2012; Tarhouni et al., 2007) and frequent droughts (Thornton et al., 2009; Vetter et al., 2020) which do not favour the persistence of certain grass species on the rangelands (Villagra et al., 2009; Thornton et al, 2015). Reseeding in conjunction with ridges and brushwood cover produced higher biomass (Table 3.6) and this raises to two critical factors; (i) Soil seed banks on semi-arid communal rangelands were depleted (Fenner and Thompson, 2005) and (ii) Grass species diversity on the rangelands had decreased a lot (Vandvik et al., 2016; Squires et al., 2018). Further to that line of thinking, the Control plot contained only annual grass species which had two limitations; poor forage value and low biomass production (Getbalew and Alemneh, 2019).

Results of the trial also indicated that plant species diversity was an important matrix in the biomass production value chain (Cowlishaw and Alder, 2009; Squires et al., 2018). Due to several years of unsustainable utilization practices, plant species with good forage value disappeared, creating a void hard to fill on semi-arid communal rangelands (Holechek et al., 2004). Farmers are reminded of the void by yearly feed shortages, some of them inflicted huge livestock mortalities in the past, which snatched away food security and livelihoods from their clasp (Day et al., 2003; Thornton et al., 2015). For livestock production to remain sustainable, reconstruction of the rangelands is needed in semi-arid communal areas (Savory and Butterfield, 2016; Scholz, 1995; Williams and Shepherd, 1991). Results of the different treatments have demonstrated this, an indication that the intervention has merits such as ecosystems balance and natural habitats, increased species diversity and high biomass production which all favour livestock production (Scherber et al., 2010; Squires et al., 2018).

3.5.5 **Forage value of introduced grass species**

While treatments were different, results of the trial show a constant trend in the forage value of all introduced grass species (Table 3.1). Grass species such as; *Schmidtia pappophoroides*, *Heteropogon contortus*, *Urochloa mosambicensis*, *Eragrostis trichophora*, *Chloris virgata*, *Digitaria eriantha*, *Eragrostis superba* which are all members of the sweet veld grass communities were introduced by reseeding (Gibbs Russel et al., 1991; Mugandani et al., 2012).

Although all the introduced grass species had good forage value (Hammond et al., 2014) and of economic importance to livestock production, it remains unknown why there were no forbs species with good forage value in all the treatments (Gioria et al., 2012; Vandvik et al., 2016). Certain forb species constitute livestock diets hence their presence in herbaceous plant communities is necessary (Brown and Bugg, 2001). In addition to providing livestock fodder, forb species are cover plants, which offer soil protection and enhancing biodiversity in plant communities (Vandvik et al., 2016). Forb species with poor forage value observed on the treatments were; *Apium leptophyllum* and *Borreria scabra*. Both had similar characteristics to those of observed annual grass species; *Tragus berteronianus*, *Eragrostis viscosa* and *Aristida barbicollis*; which produce little cover and biomass hence were not of economic importance in the livestock production value chain. Unsustainable rangeland management practices constrain the persistence and perpetuation of forbs species with good forage value in semi-arid communal areas. Land is communally owned and administered by local authorities such as Rural District Councils (RDCs). This factor exposes semi-arid communal rangelands to unrestricted abuse leading to degradation.

3.6 Conclusion

Reseeding recharges depleted soil seed banks and enhance effective restoration of degraded rangelands. It addresses species diversity and cover, it restores ecosystems and habitats as well as increasing biomass production, which are all beneficial attributes to semi-arid communal rangelands, which have endured degradation and low productivity for a long time. The intervention is affordable, practical and cheap to implement making it ideal for semi-arid communal rangelands which are constrained by degradation. Results of the trial present a good opportunity for development agents in Public and Private Extension Services to adopt the technology and upscale it in semi-arid communal areas where climate change and degradation have compromised rangelands.

3.7 Recommendations

Development agents in Public and Private Extension Services should adopt the technology and validate it at a larger scale in semi-arid communal rangelands. They must start with awareness campaigns and trainings to sell the technology to farmers to get buy-in of the idea, which will make adoption and implementation of the technology successful. The approach has advantages in that while reseeding is being implemented, rangelands will be rebuilt which will increase species diversity and productivity. The intervention must be introduced in form of a community project or competition where hard working communities receive incentives, prizes or look-and-learn visits as motivation.

CHAPTER FOUR

4 Reseeding a degraded semi-arid communal rangeland using livestock

4.1 Introduction

Semi-arid communal rangelands are unique biomes closely-knit with availability of services, goods, and food which have significant importance in livelihoods and micro-economies of low-income people (Chaminuka et al., 2014; Mudzengi et al., 2017). In Zimbabwe semi-arid rangelands occupy sixty-five percent of the total area of the country and are home to most communal farmers (Mugandani et al., 2012). They are the basis of extensive livestock production, which provides a cheap source of livestock feed (Karubian and Duraes, 2009; Boval and Dixon, 2012; Carlier et al., 2009). Animal - plant interaction dates back a long time demonstrating a mutualistic relationship between the two (Jones, 2017; Cayssials and Rodriguez, 2006; Cingolani et al., 2005). Plants are important in the lives of livestock, which enables them to accomplish certain processes such as foraging, digestion, movement, work, growth and reproduction during their life time (Brown and Bugg, 2001). Plant communities must be inhabited by self-sustaining plants also known as perennials whose main purpose is to satisfy nutritional requirements of grazers to their benefit (Hammond et al., 2014; Kgosikoma et al., 2015). Rangeland condition, is one variable whose influence on the rangeland's ability to provide fodder to animals is great (Holechek et al, 2004; Manske, 2005). Poor rangeland condition triggers feed shortages, especially during the dry season, which often catch many communal farmers in semi-arid areas unprepared (Higginbottom and Symeonakis, 2014; Kassahun et al., 2008b; Thornton et al, 2015).

Maintaining balance between utilization and rangeland sustainability during plant-animal interactions is hard (Izzauralde et al., 2011; Cowley and McCosker, 2011). Such interactions usually alter species composition, diversity and rangeland productivity (Eldridge et al., 2016). Several factors influence the condition of plant communities (Holechek et al., 2004; Manske et al., 2005). Biotic (human activities) and abiotic factors (climatic conditions) contribute to the complexities on sustainable rangeland management and utilization in semi-arid communal rangelands (O'Reagain and Scanlan, 2011). While climatic conditions usually suppress rangeland productivity, anthropogenic activities are major contributors to challenges affecting semi-arid communal rangelands (Ibanez et al., 2007; Liu et al., 2009). Such factors include rangeland fragmentation (Senda et al., 2020), over stocking and over utilization (Gamoun et al., 2015). The impact of the numerous challenges is rangeland degradation (Cingolani et al., 2005;

Bo et al., 2013). It causes further complications such as reduced standing biomass and poor species diversity which drive feed shortages in semi-arid communal areas (Deng et al., 2013; Derner et al., 2017). Livestock production can only be sustainable through holistic adoption of remedial interventions to reverse degradation in semi-arid communal areas (Rohde et al., 2006; Kassahun et al., 2008). Degraded land is unproductive due to loss of vigour and biodiversity which cause its failure to produce fodder for livestock (Squires et al., 2018; Buzhdygan et al., 2020; Petermann et al., 2021)). Consequently, rangeland health and productivity must be nurtured to enhance productivity in semi-arid communal areas where degradation is a constraint to livestock production (Mestdagh et al., 2003; Thornton et al., 2015). This is important because livestock production is the cog that turns the wheels of food security and livelihoods in semi-arid communal areas (Palmer and Bennett, 2013; Malusi et al., 2021). Restoration is the intervention which must improve production and animal off-take in semi-arid communal rangelands because healthy land is more productive.

4.2 Fighting fire with fire on semi-arid communal rangelands

Plant - animal interaction alters plant communities when due care is not exercised (Meyer et al., 1957; Karubian and Duares, 2009; van der Waal et al., 2011). However, the interaction is also beneficial to the environment where animals are used to restore and manage the land (Savory and Butterfield, 2016; Nordborg and Roos, 2016). A study by Jones et al (2017) offers encouraging scientific proof that animals are effective mediums of reseeding damaged ecosystems and bringing them back to their climax condition. Degradation (Bai and Dent, 2006; Bennett et al., 2012), which is rife on semi-arid communal rangelands, is possible to reverse through careful planning of animal movements across landscapes, as this has a direct impact on how plant seeds are deposited (O'Connor and Pickett, 1992; Cousens et al., 2010). The practice though not very common, and rather cumbersome to implement in a communal set up, can demonstrate how the same animals that overran ecosystems, can also rebuild what they destroyed (Saunders et al., 1993; Savory and Butterfield, 2016; Shinde and Malshe, 2015; Tessema et al., 2011). Degraded land is not productive due to loss of biodiversity and productive potential hence it requires corrective intervention to enhance water and food insecurity (Scholz, 1995; Tila et al., 1996; Cousens et al., 2010). Several benefits are created by restoration which include healthy land, biodiversity and improved infiltration which all amount to productivity. Healthy land offers more fodder to livestock thus increasing chances of food security supported by livestock production.

4.2.1 **Objectives of the study**

The main objective of the study was to evaluate the effect of livestock seed dispersion on degraded semi-arid communal rangeland

Specific objectives were to:

- Investigate grass species dispersed by livestock
- Determine the ideal period for using livestock to disperse seed
- Determine the growth habit of species dispersed by livestock
- Determine the palatability of species dispersed by livestock

4.3 Materials and methods

4.3.1 **Study site**

The study was conducted at Pelele Village, Ward 12, (21^0 30' S 28^0 30' E), 60 km south west of Gwanda town in Matabeleland South Province. The village has three lines; Likakeng, Mbirwane and Nyikanyoro, which have 160 households distributed among them. Although communal farmers in this village practice a crop-livestock system of agriculture, livestock production is the better agricultural option, because they are living in a semi-arid region. Livestock in the area comprise 500 cattle, 300 donkeys, 600 goats and 250 sheep, all grazed on communal rangelands. Grazing space is steadily declining due to fragmentation caused by high demand for cropping land (Hlatshwayo, 2017; Senda et al., 2020).

The site is located in agro-ecological region (AER) V, which is characterized by low and highly variable rainfall and annual mean is below 450mm (Mugandani et al., 2012). The rainy season usually commences in November and tails off in March. The soils are sandy loams. Dominant tree species are *Vachellia tortilis*, *Terminalia randii*, *Dichrostachys cineria*, *Lonchocarpus capassa*, *Combretum apiculatum*, *Cassia abbreviatta*, *Gymnosporia senegalensis*, *Colophospermum mopane*, *Grewia flavescens*, *Grewia monticola*, and *Gardenia volkenzii* (Kwembeya and Takawira, 2002*)*. The dominant grass species are *Aristida barbicollis*, *Brachiaria deflexa*, *Chloris virgata*, *Eragrostis viscosa*, *Panicum novermnerve*, *Schmidtia pappophoroides* and *Tragus berteronianus* (Gibbs Russell et al., 1991; Timberlake et al., 2007) and forbs such *Apium leptophylum*, *Borrreria scabra*, *Ipomoea alba* (Mangosho and Mupambwa, 2013) and nutsedges *Fimbristylis disticha* and *Cyperus angolensis* (Gibbs Russell et al., 1991). One invasive cactus species *Cylindriopuntia fulgida* threatens the rangelands and livestock.

4.3.2 **Experimental design**

The experiment was RCBD, forty animals were randomly selected from a large herd with a factorial concept and allocated to four treatments, each treatment had ten animals.

During the peak growing season, seven days after grass seed had started to mature, the herd of cattle was grazed for 24 hours, on a site with good species diversity and cover. At the end of twenty-four hours, the animals were taken out of the site and penned overnight. On the following day, ten animals were randomly selected from the herd and allocated to Treatment 1, each animal was followed and when it dropped dung, 20g of dung were collected from the dung, labelled and taken to a sample room at Matopos Research Institute and dried under shade. On the fourteenth day the animals were taken again to the site and grazed for 24 hours and taken out at the end of the day. On the following day, 20g of dung were collected from each animal out of the second set of ten randomly selected animals. The dung was also taken to a sample room and dried under shade. The second set of ten animals were allotted to Treatment 2. The process was repeated for Treatment 3 on the twenty-first day and Treatment 4 on the twenty-eighth day.

After all the collected cow-dung samples had dried enough, each sample was taken out of the sample bag, gently crushed and put back in its respective bag. River sand was collected and heated in a dehydrator at 80^{0}C for 24 hours to kill all seeds present (Patel et al., 2020; Ardiarini et al., 2021). The heated river sand was allowed to cool off and spread in forty-one germination trays; forty for the treatments and one for the control. Germination trays were filled with the scarified river sand, leaving an allowance of 3cm at the top of each tray for watering, the trays were labelled and arranged in their treatments in a greenhouse. Each crushed cow-dung sample was spread on top of the scarified river sand in the labelled germination trays. For the Control, a soil sample collected from a degraded (Kiss et al., 2012) site was spread on top of the scarified river sand. Once germination started, the seedlings were counted and recorded. Germination trays were watered until all plants flowered, and became easy to identify (Gibbs Russell et al., 1991; Poilecot et al., 2007; Kwembeya and Takawira, 2013). After identification of all plants in the treatments and control, were uprooted.

Table 4.1: Treatments of the experiment and sampling days

Treatment	Sampling day after seed maturity
1	7
2	14
3	21
4	28
Control	Soil seed bank from the rangeland

4.4 Data analysis

4.4.1 **Statistical model and procedure**

All graphical presentations were done using Microsoft Excel and species frequencies were computed using a Statistical Package for Social Scientists (SPSS, IBM version 21, 2018). Treatments were specified as a factor and number of species observed as response variables. A trend equation was fitted over the number of days when animals were sampled and the R-square was fitted as a coefficient of determination.

A Linear trend model of the form (eq 2) below was fitted to the number of seedlings observed for the data.

$$Y = \alpha + bX \qquad \text{eq(2)}$$

Where Y is the number of species observed after a number of days when animals were sampled (7, 14, 21, 28)

X is the independent variable, day at count of the species in the randomly selected animals

b is the coefficient to the trend equation

α is the constant term

4.5 RESULTS

Diversity of observed species was good in all the treatments for both grass and forb species (Table 4.1) indicating that animals are reliable agents of seed dispersion (Gokbulak, 2006; Forest et al., 2015). Herbaceous species observed in treatments 1 and 2 were more than the ones observed in treatments 3 and 4 (Gioria et al., 2012; Long et al., 2008), however, they were lower in the Control plot. The observed herbaceous plant species indicated diversity and good proportions of both grass and forb species, displaying a considerable similarity between plant communities at treatments and the ones observed on the rangeland. Although animals sometimes eat *Acacia* pods, their seedlings were not observed in all treatments suggesting that they may not have been ingested during grazing and browsing. It is also probable that during the time the animals were pushed to graze in a site with good species diversity, Acacia pods were not yet available, hence animals could not access them.

Grass species at Treatment 1 included six palatable perennial grass species; *Eragrostis superba*, *Panicum maximum*, *Cynodon dactylon*, *Eragrostis habrantha*, *Eragrostis rigidior* and *Eragrostis trichophora*; two palatable annuals; *Urochloa panicoides* and *Dactyloctenium aegyptium*; (Gibbs Russell et al., 1991; Poilecot et al., 2007; Kwembeya and Takawira, 2013) Three palatable forb species; *Triumfetta rhomboidea*, *Leucas martinicensis* and *Portulaca oleracea* (Mangosho and Mupambwa, 2013) were observed. One unpalatable perennial grass species *Tricholaena monachne* was observed while more unpalatable annual grass species; *Eragrostis* species, *Tragus berteronianus*, *Eragrostis aspera*, *Setaria interpillosa* and *Aristida barbicollis*. (Chippindall and Cook, 1976; Gibbs Russell et al., 1991) were observed. Forbs with poor forage value included; *Altenanthra repens*, and *Erigeron floribundus.* This method of reseeding can be useful in semi-arid communal areas, where a lot of effort is required to address the prevalent degradation which threatening livestock production (Gokbulak, 2006; Aboling et al., 2008).

Table 4.2: Proportions of plant species observed at treatment 1

Treatment	Species	Frequencies	Proportions (%)
1	Es	13	16.9
	Pm	10	13.0
	Esp	8	10.4
	Cd	7	9.1
	Eh	7	9.1
	Efl	5	6.5
	Er	4	5.2
	Tb	4	5.2
	Eas	3	3.9
	Fb	2	2.6
	Pol	2	2.6
	Sin	2	2.6
	Up	2	2.6
	Aas	1	1.3
	Ab	1	1.3
	Are	1	1.3
	Dae	1	1.3
	Et	1	1.3
	Lma	1	1.3
	Tm	1	1.3
	Trh	1	1.3

Table 4.3: Proportions of plant species observed at treatment **2**

Treatment	Species	Frequencies	Proportions (%)
2	Sve	23	28.0
	Pm	12	14.6
	Et	7	8.5
	Dae	6	7.3
	Esp	6	7.3
	Cd	5	6.1
	Up	5	6.1
	Efl	4	4.9
	Eh	3	3.7
	Fb	2	2.4
	Lma	2	2.4
	Tb	2	2.4
	Trh	2	2.4
	Ale	1	1.2
	Cbe	1	1.2
	Er	1	1.2

Herbaceous plants at Treatment 2 showed higher species diversity in both grasses and forbs (Table 4.3) and their forage value was good. Five palatable perennial grass species were observed; *Panicum maximum*, *Eragrostis trichophora*, *Cynodon dactylon*, *Eragrostis habrantha* and *Eragrostis rigidior*. Only two palatable annual grass species were observed; *Dactyloctenium aegyptium* and *Urochloa panicoides* (Gibbs Russell et al., 1991; Poilecot et al., 2007; Kwembeya and Takawira, 2013). Three forbs species had good forage value; *Leucas martinicensis*, *Triumfetta rhomboidea* and *Commelina benghalensis* (Mangosho and Mupambwa, 2007). However, three annual grass species with poor forage value were observed; *Sorghum versicolor*, *Eragrostis* species and *Tragus berteronianus* (Chippindall and Cook, 1976) while unpalatable forbs included only *Apium leptophylum*. Proportions of species were also good indicating species diversity in the site where animals were grazed prior to collection of dung samples (Gokbulak, 2006; Aboling et al., 2008). One factor that comes out clearly is that livestock-mediated reseeding is dependent on timing as indicated by the numbers of species at

Treatments 1 and 2 (Tables 4.2 and 4.3) where dung samples were collected during the first fourteen days of the observation period (Gokbulak, 2006; Tessema et al., 2011).

Table 4.4: Proportions of species observed at treatment 3

Treatment	Species	Frequencies	Proportions (%)
3	Pm	13	26.0
	Es	12	24.0
	Efl	7	14.0
	Lja	5	10.0
	Sve	5	10.0
	Bp	2	4.0
	Ale	1	2.0
	Can	1	2.0
	Lma	1	2.0
	Up	1	2.0

Plant species diversity depressed at Treatment 3, (Table 4.4) indicating that animals ingested less seeds as days progressed towards the end of the observation period. Only two palatable perennial grass species; *Panicum maximum* and *Eragrostis superba* and two palatable annual grass species; *Urochloa panicoides* and *Cyperus angolensis* (Gibbs Russell et al., 1991; Poilecot et al., 2007) which is a sedge although it was listed as a grass species were observed. Three forbs palatable species; *Bidens pilosa*, *Lippea javanica* and *Leucas martinicensis* were observed. Two of the forbs were unpalatable; *Erigeron floribundus* and *Apium leptophylum* (Mangosho and Mupambwa, 2013). This indicated the importance of correct timing where livestock-mediated reseeding is being implemented.

The methodology has a weakness where good timing is not properly adhered to (Aboling et al., 2008), however, it is still an effective way of rebuilding degraded rangelands considering the numbers of grass species at Treatments 1 and 2 (Tables 4.2 and 4.3) respectively which were observed at the treatments. The intervention could benefit semi-arid communal rangelands which are degraded, more so considering that farmers in those areas have animals for use.

Table 4.5: Frequencies of species observed at treatment 4

Treatment	Species	Frequencies	Proportions (%)
4	Pm	4	16.0
	Efl	3	12.0
	Lja	3	12.0
	Are	2	8.0
	Cd	2	8.0
	Trh	2	8.0
	Aas	1	4.0
	Bp	1	4.0
	Can	1	4.0
	Dt	1	4.0
	Eh	1	4.0
	Er	1	4.0
	Lma	1	4.0
	Sve	1	4.0
	Up	1	4.0

4.5.1 **Plant species observed at Treatment 4**

Depression of plant species diversity was noticeable at Treatment 4 (Table 4.5), the treatment was in the final days of the observation period (Aboling et al., 2008). The treatment presented four palatable perennial grass species; *Panicum maximum*, *Cynodon dactylon*, *Eragrostis habrantha* and *Eragrostis rigidior*. There were two palatable annual grass species; *Urochloa panicoides* and *Cyperus angolensis* which although it was classified under grass species is a sedge. Three annual grass species *Eragrostis aspera*, *Sorghum versicolor* and *Digitaria ternata* had no forage value. There were four palatable forbs species *Leucas martinicensis*, *Bidens pilosa*, *Triumfetta rhomboidea* and *Lippea javanica* while two forbs *Alternanthera repens* and *Erigeron floribundus* were unpalatable. Numbers of observed grass species were reduced as the observation period drew to a close indicating that timing is crucial in using animals to disperse grass species seeds.

Table 4.6: Proportions of species observed at Control

Treatment	Species	Frequencies	Proportions (%)
Control	Um	19	31.7
	Ab	13	21.7
	Fb	12	20.0
	Esp	11	18.3
	Tb	2	3.3
	Bd	2	3.3
	Spa	1	1.7

Observed herbaceous species at Control plot indicated degradation signs on the site where the soil sample was collected. There were only two grass species with good forage value; *Schmidtia pappophoroides* and *Urochloa mosambicensis* while unpalatable annual grass species were four; *Brachiaria deflexa*, *Tragus berteronianus*, *Eragrostis* species and *Aristida barbicollis*. The herbaceous species at Control were a true representation of a degraded semi-arid communal rangeland (Vandvik et al., 2016; Shi et al., 2020), where good species were grazed to extinction. Consequently, the rangelands were now dominated by annuals which apart from having no forage value produced low biomass. Such rangelands require restoration to bring back good grass species ideal for grazing.

Key

Grass species

Ab	*Aristida barbicollis*
Bd	Brachiaria deflexa
Can	Cyperus angolensis
Cd	*Cynodon dactylon*
Dae	*Dactyloctenium aegyptium*
Dt	Digitaria ternata
Fb	Forbs
Eas	*Eragrostis asperas*
Eas	*Eragrostis asperas*
Eh	*Eragrostis habrantha*
Er	*Eragrostis rigidior*
Es	*Eragrostis superba*
Esp	*Eragrostis* species
Pm	Panicum maximum
Sin	Setaria interpillosa
Spa	Schmidtia papphophoroides
Sve	Sorghum versicolor
Tb	*Tragus berteronianus*
Tm	Tricholaena monachne
Up	*Urochloa panicoides*

Forbs

Aas	Achyranthes aspera
Ale	*Apium leptophyllum*
Are	Alternanthera repens
Bp	*Bidens pilosa*
Cbe	Commelina benghalensis
Efl	*Erigeron floribundus*
Lja	*Lippea javanica*
Lma	*Leucas martinicensis*
Pol	*Portulaca oleracea*
Trh	*Triumfetta rhomboidea*

4.5.2 General observation on plant species at treatments

There were more species observed in Treatments 1 and 2 compared to Treatments 3 and 4 (Figure 4.1), showing that animals ingested more seed during the first 14 days of the observation period (Sagario et al., 2020). However, as days progressed fewer species were observed, indicating that less grass seeds were ingested during that period. It is probable that as grass seeds mature, they tend to fall to the ground as a soil seed bank replenishment mechanism. Therefore, by the time animals were moved to graze, there were fewer seeds on the grass species. The observation is that timing is a critical factor in the process (Aboling et al., 2008). The activity is most effective during the first fourteen days when seeds have strated to show physiological maturity.

While results of the experiment show positive signs of effectiveness in rebuilding degraded rangelands, it must always be borne in mind that timing determines its success (Aboling et al., 2008). Poor timing is one major short coming of the technology, however, it demonstrates great potential of bringing a solution for degradation in semi-arid communal areas. The simple nature of the technology is set to enhance its adoption in rural communities it stands to bring change to communal rangelands.

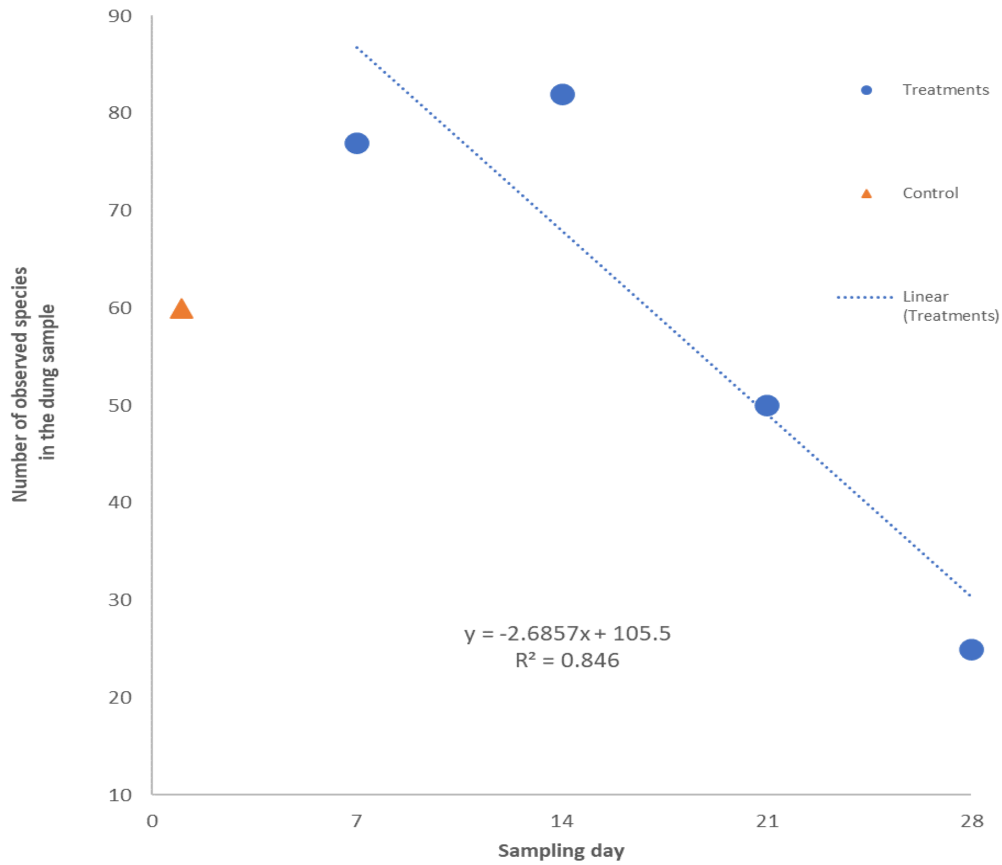


Figure 4.1: Observed seedling densities at a 28-day cattle grazing cycle

Notes:

- A correlation between number of species observed in dung sample and time/day at sampling strongly exists
- Coefficient of determination, R^2 implies amount of variability explained by the fitted line, in this regard is above 84%

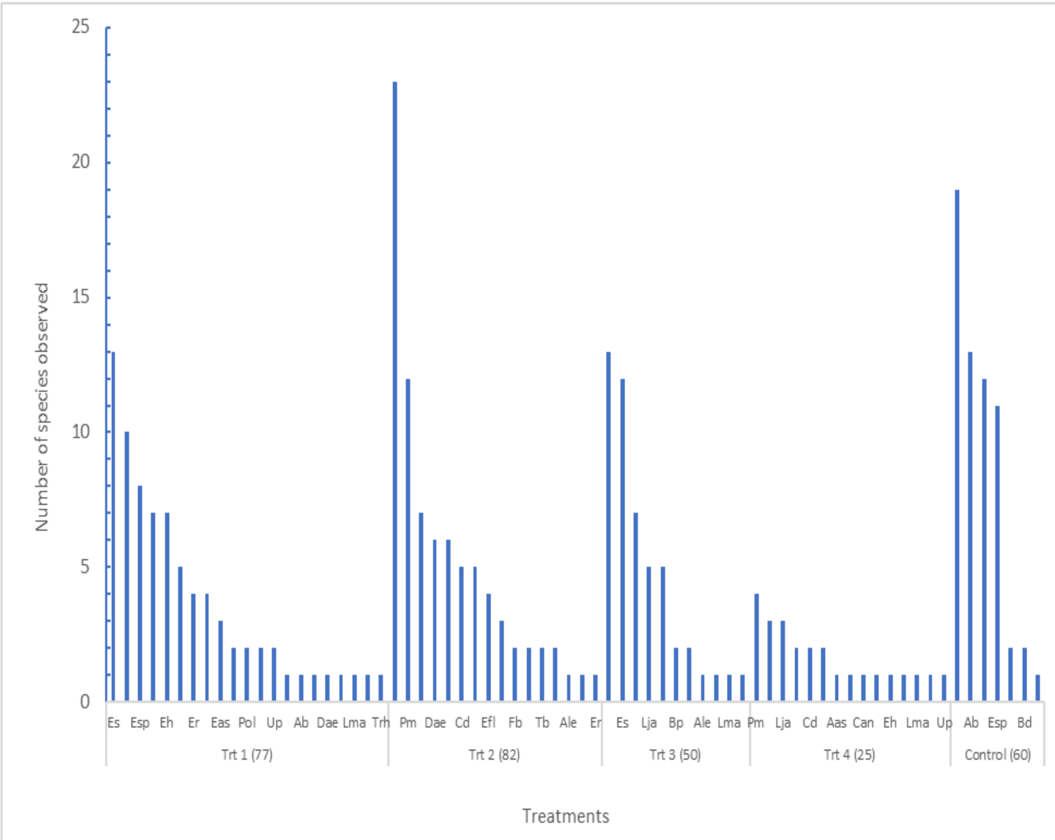


Figure 4.2: Proportions of species observed at different treatments

Proportions of observed species were high during the first fourteen days of observation (Figure 4.2) at Treatments 1 and 2. This indicates the significant influence of time factor when a high success rate is expected out this technology. Of interest to note is that observed grass species such as *Eragrostis superba*, *Panicum maximum*, *Eragrostis rigidior* and *Eragrostis habrantha* are perennials which will add diversity and forage value to annual grass species on the rangeland as observed in the Control plot (which was a true reflection of available grass species on the rangeland). The Control plot indicated annual species only; *A*. *barbicollis*, *Eragrostis* species, *Brachiaria deflexa*, *Tragus berteronianus* and forbs while there were two perennial species; *Urochloa*.*mosambicensis* and *Schmidtia pappophoroides* (Table 4.1 and Figure 4.2).

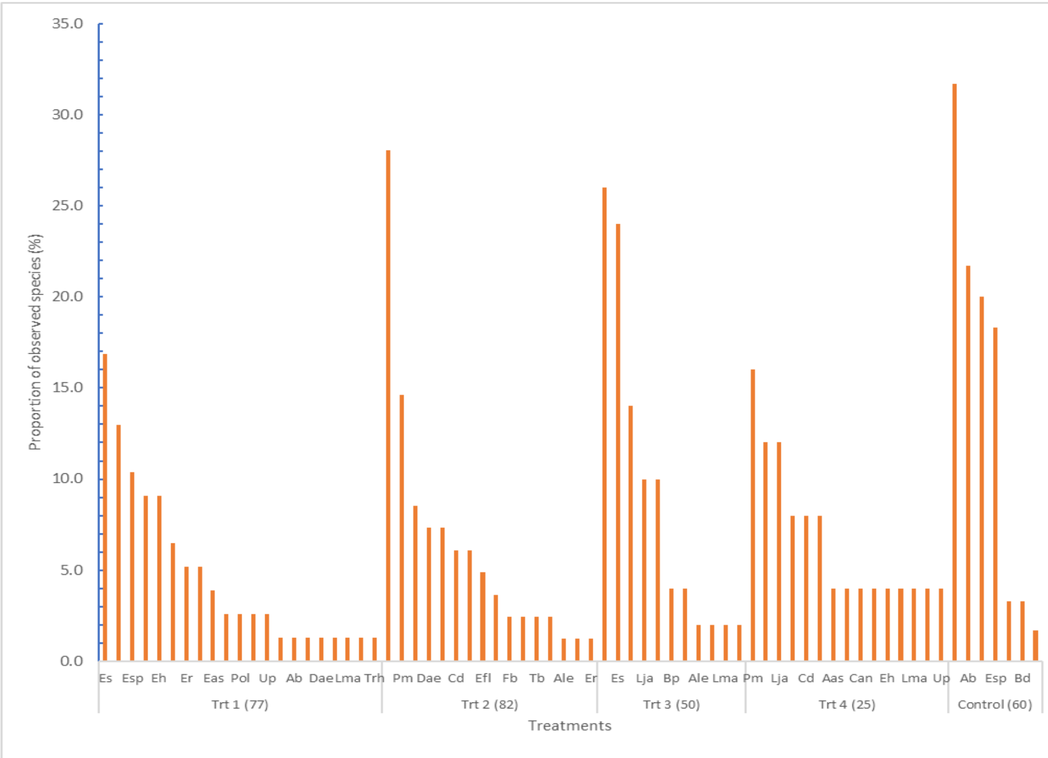


Figure 4.3: Percentages of species observed at different treatments

Observed grass and forb species at Treatments were grouped into two classes; (growth habit) to determine whether they were perennial or annual species and (palatability) to determine forage value (Figure 4.3). Both grass and forb species included annuals and perennials. The composition was good for species diversity, balance of the ecosystems and habitats. Besides providing fodder for animals, both types of plant species play important roles in the persistence and perpetuation of ecosystems, which makes their existence in an ecosystem necessary.

Table 4.7: Growth habit of grass and forb species observed from cow dung samples

Name of plant	Palatable		Type of plant		Perenniality	
	Yes	**No**	**Grass**	**Forb**	**Perennial**	**Annual**
Bidens pilosa	X			X	X	
Lippea javanica	X			X	X	
Apium leptophyllum		X		X		X
Cynodon dactylon	X		X		X	
Tragus berteronianus		X	X			X
Erigeron floribundus		X		X	X	
Triumfetta rhomboidea	X			X	X	
Leucas martinicensis	X			X		X
Dactyloctenium aegyptium	X		X			X
Aristida barbicollis		X	X			X
Urochloa panicoides	X		X			X
Portulaca oleracea	X			X		X
Eragrostis asperas		X	X			X
Eragrostis rigidior	X		X		X	
Eragrostis habrantha	X		X		X	
Eragrostis species		X	X			X
Eragrostis superba	X		X		X	
Panicum maximum	X		X		X	

Forage value of observed grass species across Treatments was good (Table 4.2), and included Cynodon dactylon, *Dactyloctenium aegyptium*, *Urochloa panicoides*, *Eragrostis rigidior*, *Eragrostis habrantha*, *Eragrostis superba* and *Panicum maximum* (Chippindall and Cook, 1976; Gibbs Russell et al., 1991). All observed grass species were palatable indicating that animals generally spread plant species with good forage value. This could probably be attributed to the selective nature practiced by animals during grazing. Some forbs species were also observed across treatments some of which were palatable such as *Bidens pilosa*, *Lippea javanica*, *Triumfetta rhomboidea*, *Leucas martinicensis* and *Portulaca oleracea* (Mangosho and Mupambwa, 2013; Kwembeya and Takawira, 2013). Although *Heteropogon contortus* is ubiquitous, and can be found in many habitats and soil types, it was not observed among observed grass species. It is highly probable that the reason for this was due to its seeds which are little spikes hence animals shunned it at grazing as they did not want to injure their mouths.

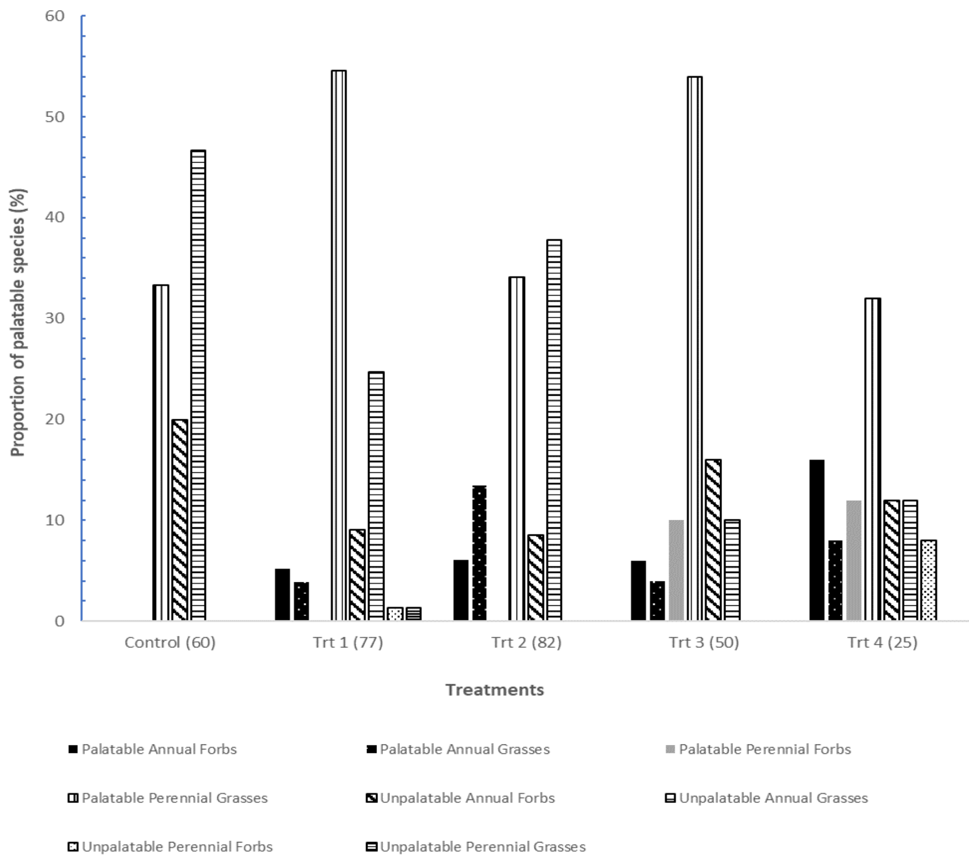


Figure 4.4: Proportions of different classes of grass species across treatments

One interesting observation (Figure 4.5), is that animal-reseeding only brings good forage value species of annuals and perennials in both grasses and forbs. This is important for semi-arid communal rangelands where degradation altered species composition.

4.6 DISCUSSION

4.6.1 **Animal-grass interaction**

Animal-grass interaction dates back a long time indicating either a mutual co-existence between the two or antagonistic where one species depends on the other (Solanki and Naik, 1998; Soder et al., 2007; Abrahamson, 2011). However, high demand for animal products and by-products worldwide (Boval and Dixon, 2012; Steinfeld et al., 2006), is straining grass species productivity, hence their failure to compete favourably with animals' demand for fodder and remain persistent (De-Claro and Torezan-Silingardi, 2021). Heavy rangeland utilization by animals, causes disappearance of certain plant species which results in degradation (van Coller et al., 2011; Yates et al., 2000). Rangelands must continue to function efficiently in the interface of several odds including; climate change, high population pressure and rangeland fragmentation (Behnke, 2008; Senda et al., 2020; Young et al., 2013). To strengthen the mutual co-existence, animals must be used in a reciprocal manner to restore destroyed environments (Tilman et al., 1996; Forest et al., 2015; Savory and Butterfield, 2016). Rejuvenating rangelands can enhance persistence and perpetuation of plant species, and promote sustainable plant-animal interaction.

4.6.2 **Seedling populations in the different treatments**

Although animals cause rangeland degradation (Cingolani et al., 2005), results indicate that with proper management, there is high potential of using animals to reseed degraded land (Table 4.1). Large seedling populations were observed at Treatments 1 and 2, which sufficiently proves that animals are good agents of seed dispersion (Gokbulak, 2006; Cousens et al., 2010). Although observed seedling numbers decreased steadily at Treatments 3 and 4 (Aboling et al., 2008), the technology demonstrates reliability, and proves effectiveness of animals in spreading certain plant species' seeds (Tessema et al., 2011). The results raise hope that semi-arid communal rangelands which are seriously degraded, due to several years of over grazing, can be rejuvenated using animals to spread plant species seeds through dung.

The merits of using livestock to reseed semi-arid communal rangelands, are affordability and simplicity, especially considering that communal farmers are financially constrained to afford expensive intervention strategies (McNaughton et al., 1982). The intervention does not require money and besides it is user friendly for laymen who constitute the majority of smallholder farmers in communal areas. It is the obligation of research to inform extension services to enhance adoption of the technology in communal areas on a large scale. Upscaling the technology has two positive aspects; (i) Many communities will have chance to test its efficacy in reseeding rangelands and (ii) Further to validation, restoration of many ecosystems will be accomplished, resulting in stable environments (Gokbulak, 2006).

4.6.3 **Significance of using livestock to disperse seed**

Diversity of observed species in all Treatments was high (Table 4.2), which indicates efficiency of livestock seed dispersion in rangeland improvement (Sagario et al., 2020). Several years of unsustainable utilization methods of semi-arid communal rangelands resulted in extinction of good species of both grasses and forbs. Results at treatments indicate that animals are good agents for restoring lost plant species on rundown rangelands (Shinde and Malshe, 2015) however, the animals must access grass seeds first. Contrary to lower numbers of observed species in the Control plot where mainly annual grass species such as *Aristida barbicollis*, *Eragrostis* species, *Tragus berteronianus*, *Brachiaria deflexa* and forbs were observed, treatments had more perennial grass species such as Schmidtia *pappophoroides*, *Eragrostis rigidior*, *Eragrostis habrantha, Eragrostis superba* and *Panicum maximum* (Chippindall and Cook, 1976; Gibbs Russell et al., 1991; Kwembeya and Takawira, 2013) One question that can be asked is; why is it was so? The probable response can be; the selective behaviour practiced by animals during grazing, causes good quality grass species to be picked first, and so on, seeds of such species will be spread (Gokbulak, 2006; Dongre, 2007).

Both annual and perennial grass species play important roles on the environment, hence their presence in ecosystems is equally crucial (Carlier et al., 2009). Unlike annual grass species, perennials largely depend on tillers for regeneration enabling these species to provide soil protection all the time. However, because perennial species are highly preferred by grazers (Eldridge et al., 2016) and several years of unfavourable climatic conditions (Fuhlendorf et al., 2001), semi-arid communal rangelands end up degraded (Deng et al., 2013). In addition to soil protecting, perennial grass species enhance high productivity, due to their big culms and leaves (Day et al., 1997). In semi-arid areas, these attributes can be beneficial, because rangeland productivity is generally low, yet the areas are major contributors to the livestock production industry (FAO, 1992; Thornton et al., 2015). Semi-arid communal rangelands have been constrained by annual feed shortages for long (Hargreaves et al., 2004), which sometimes cause huge livestock mortalities (Day et al., 2003), inducing food insecurity in many households.

Results indicate great potential for a symbiotic plant-animal interaction to be initiated in semi-arid communal areas for the benefit of the environment (Gokbulak, 2006; Aboling et al., 2008)

The absence of *Heteropogon contortus* among observed plant species at all treatments, despite its ubiquitous nature in all veld types of the country (Mugandani et al., 2012) is unexplainable, and warrants further investigation. However, it is probable that it was shunned by animals (Bao et al., 2010; Meyer et al., 1957) because its seeds are like little spikes which when grazed, can cause irritation and injuries in the mouths of animals. The conspicuous absence of the grass among observed species was consistent in all treatments, raising suspicion of a cause behind it. Diversified forb species were observed at treatments which included; *Bidens pilosa*, *Lippea javanica*, *Triumfetta rhomboidea*, *Leucas martinicensis* and *Portulaca* olerace*a* (Mangosho and Mupambwa, 2013) which indicates the efficacy of animal seed dispersion in enhancing species diversity on rangelands.

4.6.4 **The correlation of time and animal mediated seed dispersion**

While rangeland reseeding using animals is effective as indicated by the trial results the methodology's success is very much dependent on proper timing (Aboling et al., 2008). Observed species numbers were high during the first two weeks (Figure 4.1), but decreased steadily in the last two weeks of the observation period. The peak growing season, is the time when most grass species' seeds mature. Therefore, using animals during this period enhances higher chances of them picking more plant seeds at grazing (Gokbulak, 2006). This method of seed dispersion is reliable and effective in reseeding derelict environments. However, failure to observe proper timing can compromise effectiveness and reliability of the methodology (Bao et al, 2010; Meyer et al, 1957).

Timing when to expose animals to the grass and re-exposing grass to the animals is critical to ensure physiologically mature grass seeds are ingested and deposited on the environment in need of reseeding (Savory and Butterfield, 2016). This answers a question which adopters of the technology may likely ask like "when should animals go and "harvest" seeds of grass species which should be dispersed on a degraded site? It is critical to note that most agricultural activities are dependent on accurate timing for their success (Aboling et al, 2008; Shinde and Malshe, 2015; Tessema et al., 2011). Variations of timing in agricultural production, no matter how small the variability may be, can have serious consequences on quality of a product, and should be avoided by adhering to the appropriate time when performing an agricultural activity. To a livestock farmer, the most important crop is grass, because it is what animals convert into items that are beneficial to man.

4.6.5 **Forage value of plant species observed in treatments**

A large number of observed species had good forage value (Table 4.2 and Figure 4.4) which proves further the selective graving behavior of animals (Bao et al., 2010). Classification of observed plant species according to palatability, was based on information provided by Chippindall and Cook (1976) which shows the grazing value of two hundred and forty grass species of Southern Africa. Palatability of plant species was uniform across treatments in both annuals and perennials for both grass and forb species. Using animals to reseed disturbed environments, can be viewed in a way as adding value to the plane of nutrition of a rangeland (Meyer et al., 1957). Plant species' seeds dispersed by animals have a superior nutritive value (Brown and Bugg, 2001). The forage value of forbs compares favorably with browse which has nearly 30% crude protein content (Mukungurutse, 2002). Therefore, animals stand to benefit more from diversified of plant species as this increases nutritive value.

Observed plant species at treatments tally with the ones found on sweet veld (Mugandani et al., 2012) whose nutritive value is not affected by seasons. This is contrary to *Hyperrhenia* Tall veld whose nutritive value of grasses is affected by seasons hence the name sour veld (Sasaki et al., 2012). Elsewhere in this manuscript, animal-grass interaction has been described as mutual, however, it is relevant to call it symbiotic. (Table 4.4) indicates that as animals get good quality species as they graze, they also bring back to the environment good quality species through seeds (Gokbulak, 2006; Aboling et al., 2008).

A question then arises about how semi-arid communal rangelands which are affected by degradation can be reseeded? A probable response is that animals can effectively reseed damaged environments through what Savory and Butterfield (2016) call holistic rangeland management. Results of the trial have demonstrated that livestock and the environment can have a symbiotic co-existence, while man enhances chances of food security supported by livestock production.

4.7 Conclusion

Reseeding degraded rangelands can be done successfully using animals. Due to the selective nature of grazing animals, results of the trial have opened an opportunity for demonstrating that animals can effectively reseed damaged environments with good species. This can address the issue of species diversity which affects most semi-arid communal rangelands. The reseeding method is cheap and user-friendly making it suitable to anybody, however, it must be noted that its success is very much dependent on correct timing. Although the methodology looks promising, it can be difficult to implement on communal rangelands because of the question of land ownership which is not clear. Cultural norms and beliefs can also complicate its adoption and use in communal areas due to the superstitious nature of communal people. They may have fear of the unknown and become reluctant to mix their animals with their neighbours' during implementation of the methodology. However, the technology offers chance for both Public and Private Extension Services to upscale it in communal areas where rangelands are severely degraded. This can be done through validation trials to assess effectiveness of the methodology. Awareness campaigns and trainings should precede the actual work so that communities can buy-in of the idea. This is an important aspect of the development process because communities must own projects that come to their areas to enhance sustainability.

4.7.1 Recommendations

Animal-mediated seed dispersion should be validated on communal rangelands which are badly degraded. Extension Services should take up the technology and validate it through on-farm trials. Awareness campaigns should precede validation trials to deal with superstitious beliefs that may hinder adoption of the technology. Incentives in form of prizes or organized look-and-learn tours can be used to reward hard working groups as this will entice other community groups to take up the technology.

CHAPTER FIVE

5 Adoption of fodder production by farmers in a semi-arid communal area

5.1 Introduction

Over the years, semi-arid communal rangelands have been experiencing serious degradation (Tarhouni et al., 2007; Rutherford and Powrie, 2013; Eldridge et al., 2016). The development compromises their ability to feed grazers, which is one of their core functions (Deng et al., 2013; Derner et al, 2017). Livestock production is a game-changer for semi-arid communal farmers, whose food security is threatened by annual crop failures, driven by low and highly variable rainfall ((FAO, 1992; FAO, 2001; Murungweni et al., 2016). While livestock production guarantees food security and livelihoods in the semi-arid communal sector, its sustainability is dampened by feed shortages (Yates et al., 2000; Rutherford and Powrie, 2010; Derner et al., 2017). The problem has existed for a very long time, and serious ones in the past, left farmers counting their losses after suffering huge livestock deaths (Day et al., 1997; Cingolani et al., 2005). Future livestock losses can be prevented by finding a long-term solution to feed-deficits, which would bring assurance and stability in the livestock production industry. The solution lies in adopting fodder production in semi-arid communal areas (Musalila et al., 2016). Fodder crops can solve feed shortages permanently in semi-arid regions, due to numerous benefits and good attributes.

Fodder crops can be defined as plants grown for purposes of feeding animals (Kumar et al., 2022). The plants are classified under two categories; graminoids which are sources of energy (Annicchiarico, 2004) which include *Pennisetum purpureum*, *Chloris gayana* and *Cenchrus ciliaris* and Leguminosae (Bhandari et al., 2007) which include *Mucuna pruriens*, *Lablab purpureus* and *Crotalaria juncea*) which are sources of crude protein (Mhere et al., 2002; Boller and Greene, 2010; Ekepu and Tirivanhu, 2016). Fodder crops adapt to a wide range of soil types, and can grow under both rainfed and irrigation, the only noticeable difference is in yields which are higher under irrigation (Mwembe and Tavirimirwa, 2020; Kumar et al., 2022). Fodder crops can augment the little fodder produced on rangelands and help livestock pull through the dry season safely, due to their higher yields, nutritive value and palatability (CIAT and CGIAR, 2015). During the dry season, rangelands offer low quality and quantity feed, which can be augmented by growing fodder crops, known for their high nutritive value (Cowley and McCosker, 2011; Coblentz et al., 2018). Semi-arid communal farmers are not used to the idea of creating fodder banks for their livestock. This short-coming is rectifiable through adopting fodder production and preserving it either in fresh form (silage) or in dry form (hay), so that it can be used to supplement livestock in the dry season (Musalila et al., 2016). Day et al (2003) discussed huge livestock losses experienced in semi-arid areas during two severe droughts in the early 1980s and 1990s, as sufficient proof of little or no fodder production in the semi-arid communal farming communities. Droughts are very frequent and common in semi-arid regions while farmers are slow to act despite knowing that rangelands cannot cope with the high demand for fodder due to low productivity.

Rangelands' capacity to produce sufficient fodder is low, as they are constrained by several challenges including climate change, biodiversity loss, over grazing and fragmentation (Myers et al., 2000; Behnke, 2008; Senda et al., 2020). With the situation not showing signs of improvement any time soon (Izzauralde et al., 2011), the only farmers' option, is to intervene and produce their own fodder. Livestock production is the string that keeps food security and livelihoods together in semi-arid communal areas (FAO, 1992; Tessema et al., 2014; Thornton et al., 2015). Allowing livestock losses to occur, is akin to breaking the same string. All constraints hindering rangeland performance must be dealt with to enhance sufficient fodder production for the benefit of livestock.

5.2 Economic importance of fodder production

Fodder production is good for providing cheap high-quality livestock feed, and can be taken up as an enterprise to generate family incomes. This can be achieved in two ways; (i) Producing fodder for sale to farmers who own livestock and (ii) Producing seeds for local sales or for sale to Seed Houses (CIAT and CGIAR, 2015). Communal farmers are financially constrained people, who survive on low incomes which barely cover basic family needs, therefore, introducing income generating activities for them can uplift their livelihoods (Awono et al., 2010; Angelsen et al., 2014). The few farmers who produce fodder, have only managed to feed it straight to livestock (Mhere et al., 2002; Mwembe and Tavirimirwa, 2014). However, this is an opportunity for the farmers to add value to the fodder, through production of feedstuffs such as pellets or supplementation blocks which can bring more profit to them. Value-added feedstuffs increase animal feed-intake, compared to fodder fed straight to animals, resulting in selectivity during feeding times. Animals usually start by eating the softer plant parts, leaving those with high carbon content, which causes feed wastages, and this is not acceptable in semi-arid areas.

5.3 Environmental benefit of fodder production in semi-arid regions

Land is the basis of societies, which is unfortunately buckling under immense pressure from serious degradation (Ibanez et al., 2007) largely driven by human activities (Myers, 2000; Kassahun et al., 2008) and natural forces (Izzaraulde et al., 2011). The net result of the challenges summed up is failure by semi-arid communal rangelands to produce adequate fodder to satisfy grazers. This results directly from over grazing and over stocking which cause degradation (Brown and Bugg, 2001). Livestock production in semi-arid communal areas breathes life to food security and livelihoods which are being threatened by climate change (FAO, 1992; Ibanez et al, 2007; IPCC, 2013). Sustainability of rangelands is paramount because they support livestock production, and it can become viable through fodder production in semi-arid communal areas. Fodder production is another sustainable avenue of rebuilding degraded land, at the same time enhancing rangeland resilience and availability of fodder for livestock, which for many years has been low (CIAT and CGIAR, 2015; Fraccarolli, 2015). Semi-arid communal farmers depend heavily on rangelands for their fodder requirements (Mudzengi et al, 2017). Adopting fodder production in semi-arid communal areas can reduce grazing pressure on rangelands which will allow restoration to take place gradually (Scholtz, 1995). The two sources of livestock feed; rangelands and fodder gardens can complement each other in providing livestock feed and at the same time enhancing resilience and productivity of semi-arid communal rangelands.

5.3.1 **Objectives of the study**

The main objective of the study was to investigate fodder production adoption in a semi-arid communal area

Specific objectives were to:

- Evaluate adoption of fodder production in communal areas
- Determine methods of fodder preservation preferred by smallholder farmers
- Determine livestock species mostly supplemented during the dry season
- Investigate other uses of fodder legumes identified by smallholder farmers in a semi-arid communal area

5.4 Materials and methods

5.4.1 **Study site**

The study was conducted at Pelele Village, Ward 12, 21^0 30’ S 28^0 30’ E, 60 km south west of Gwanda town in Matabeleland South Province. The village has three lines; Likakeng, Mbirwane and Nyikanyoro, and 160 households distributed among the three lines. Pelele communal farmers, practice a crop-livestock system of agriculture, however, livestock production is the better agricultural option because area is in a semi-arid region. Livestock species include; 500 cattle, 300 donkeys, 600 goats and 250 sheep, which are grazed on a communal rangeland. Grazing space is steadily declining as a result of fragmentation due to high demand for cropping land (Senda et al., 2020).

The site is located in agro-ecological region (AER) V, which is characterized by low and highly variable rainfall with an annual mean below 450mm. The rainy season commences in November and tails off in March. Soils are sandy loams. Tree species are dominated by *Vachellia tortilis*, *Terminalia randii*, *Dichrostachys cineria*, *Lonchocarpus capassa*, *Combretum apiculatum*, *Cassia abbreviatta*, *Gymnosporia senegalensis*, *Colophospermum mopane*, *Grewia flavescens*, *Grewia monticola*, and *Gardenia volkenzii* (Kwembeya and Takawira, 2013). While dominant grass species include *Aristida barbicollis*, *Brachiaria deflexa*, *Chloris virgata*, *Eragrostis viscosa*, *Panicum novermnerve*, *Schmidtia pappophoroides* and *Tragus berteronianus* (Chippindall and Cook, 1976; Gibbs Russell et al., 1991) and forbs such species as *Apium leptophylum*, *Borrreria scabra* and *Ipomoea alba* (Mangosho and Mupambwa, 2013) and nutsedge species; *Fimbristylis disticha* and *Cyperus angolensis*. One cactus species *Cylindriopuntia fulgida* was invasive and a threat to rangelands and livestock.

5.4.2 **Procedure**

A fodder production model was used and during the first year, twenty-five farmers were randomly selected and each supplied with fodder seeds; 2kg Lablab (*Lablab purpureus*), 2kg Velvet beans/mucuna (*Mucuna pruriens*) and 1kg forage sorghum (*Sorghum bicolor* L.) PVK 801 seed (Kumar et al., 2022). The farmers were trained on fodder production, preservation and utilization. After training, the farmers planted the fodder seeds, and were told they had joined a pass-on seed fodder scheme whereby each farmer would allow some of the fodder to produce seed for harvesting. The farmer would use stover to hay for supplementing livestock during the dry season. Each farmer was required to pass-on seed to five people. In the following season 125 farmers planted fodder and each passed-on the seed to five farmers. In the third season, 625 farmers planted fodder and also passed-on seed to five farmers each and in the fourth season 3125 farmers planted fodder. The pass-on seed scheme was not limited to Pelele Village farmers alone, as farmers were allowed to pass-on seed to any other five farmers of their choice in their vicinity.

A formula for determining expected number of fodder adopters

$N_F \times A^S{}_F$

Where S is the season 1, 2, 3, 4

N_F is the initial beneficiaries of fodder seeds

A_F is the number of adopters from other farmers

$N_F = 25$

$A_F = 5$

Such that S1: $25 \times 5^1 = 25 \times 5 = 125$

S2: 25 x 52 = 25 x 25 = 625………up to S4

A structured questionnaire (See Appendix for Chapter 5) was administered to 125 farmers in the village to assess effectiveness of the pass-on seed fodder scheme. The questionnaire aimed to evaluate the number of farmers who started to produce fodder for their livestock through the pass-on seed scheme.

5.5 Data analysis

5.5.1 **Statistical model and procedure**

After the questionnaires had been completed, post coding was done, followed by double entry for data integrity checks and summary reports to check for inconsistencies. The next step was to carry out descriptive statistics, frequencies, measures of central tendency and dispersion [variability etc] using SPSS IBM Version 21 (2018). Cross tabulations were carried out to test correlation between two variables.

5.6 RESULTS

The following figures and graphs help to explain survey results on fodder production adoption in semi-arid communal areas.

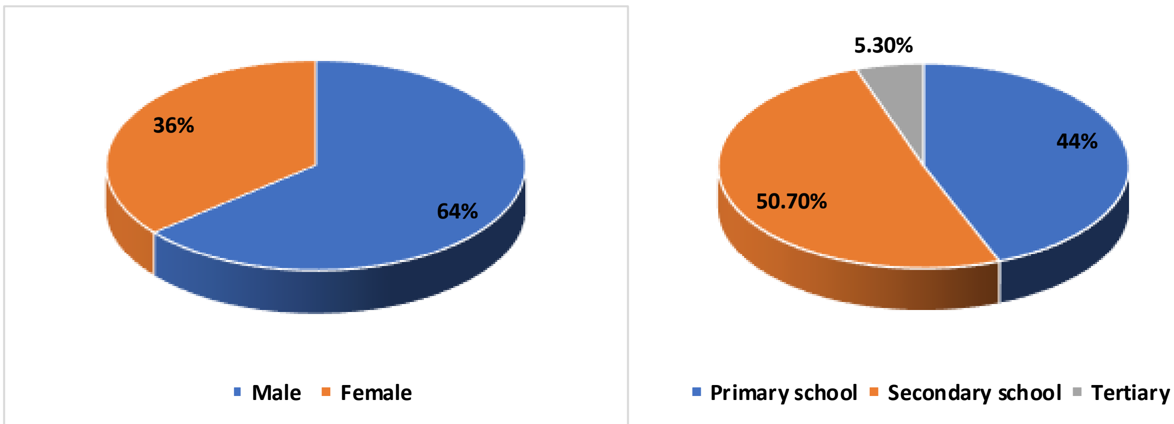


Figure 5.1: Proportions of gender and education of respondents

The majority of respondents comprised 36% females and 64% females (Figure 5.1) of whom 44% had gone through primary education, 50.7% went through secondary education while 5.3% went through tertiary education.

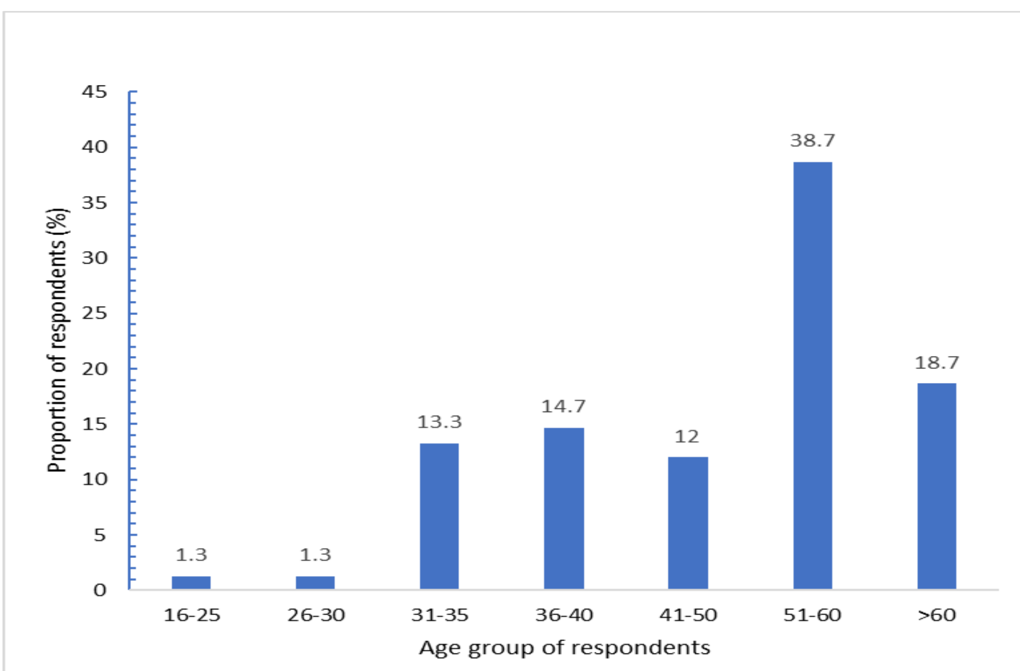


Figure 5.2: Age groups of respondents

(Figure 5.2), indicates 38.7% of respondents were in the 51 – 60 age group, 18.7%. were above 61 years. This is worrying because farming in the area is in the hands of elderly people whose energy is going down. Respondents in the 41- 50 years comprised 12%, 36 – 40 years 14.7%, 31 – 35 years 13.3% and those below 30 years constituted 2.6%. It is probable that younger people prefer to cross borders to seek employment opportunities in Botswana and South Africa due to the proximity of the two countries to the area. Farming sustainability in the area is under threat because most active farmers are in their twilight years, suggesting that there won't be continuity once they are no more.

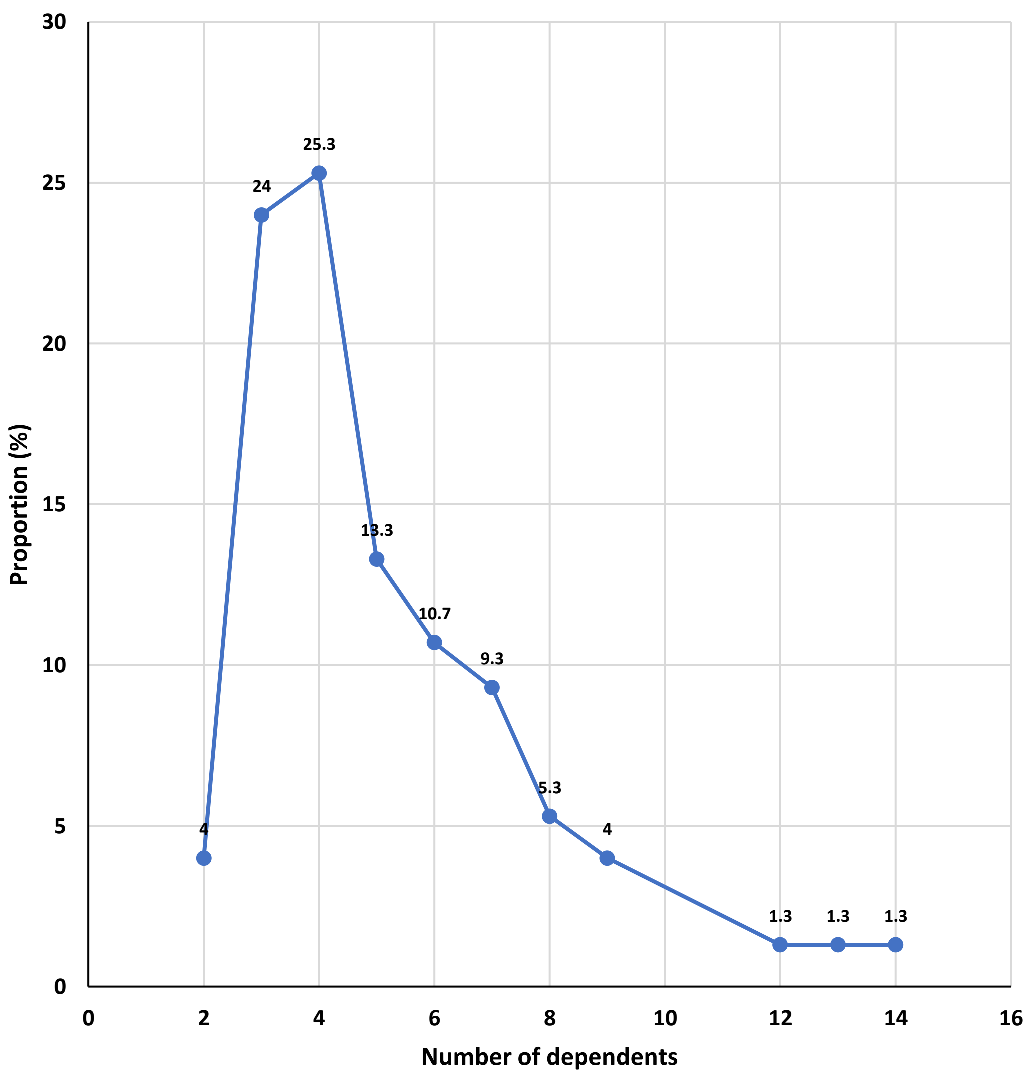


Figure 5.3: Number of dependents per respondent

Most of respondents had dependents (Figure 5.3), ranging between 2 and 14 per family, the proportions of respondents were as follows; 4 dependents were 25.3%, 3 – 24%, 5 – 13.3%, 6 – 10.7% while those with dependents above 7 were negligible.

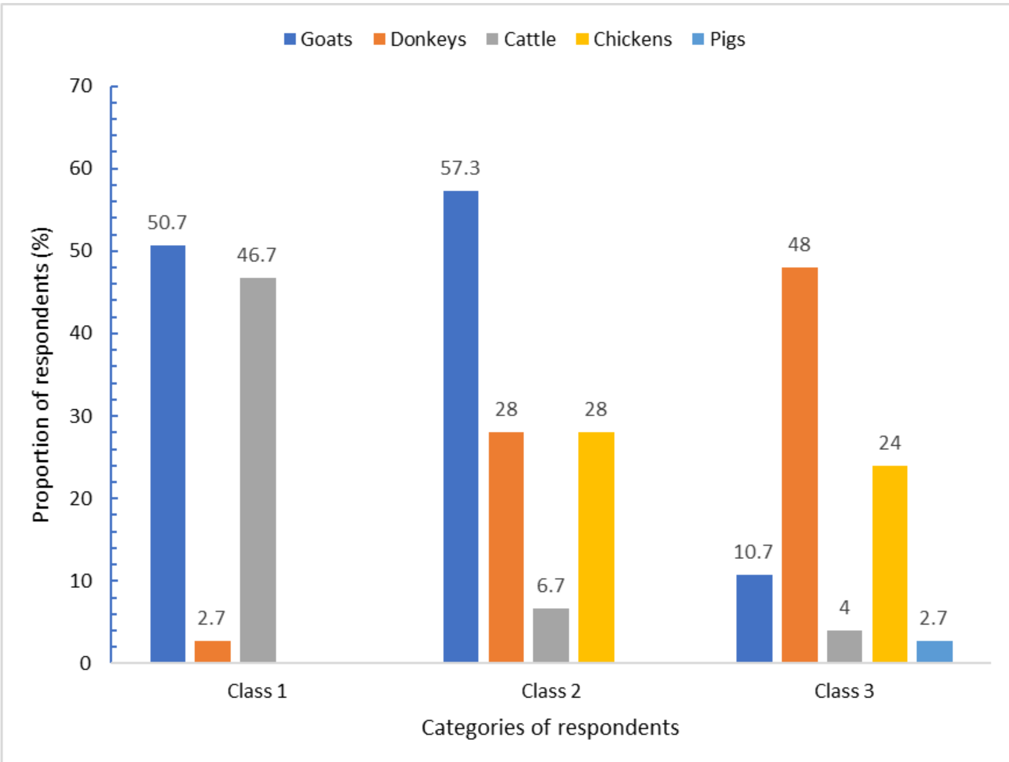


Figure 5.4: Livestock species kept by farmers in their order of importance

Respondents were categorized into three classes (Figure 5.4); Class 1 had goats, donkeys and cattle, Class 2; goats, donkeys, cattle and chickens and Class 3; goats, donkeys, cattle, chickens and pigs.

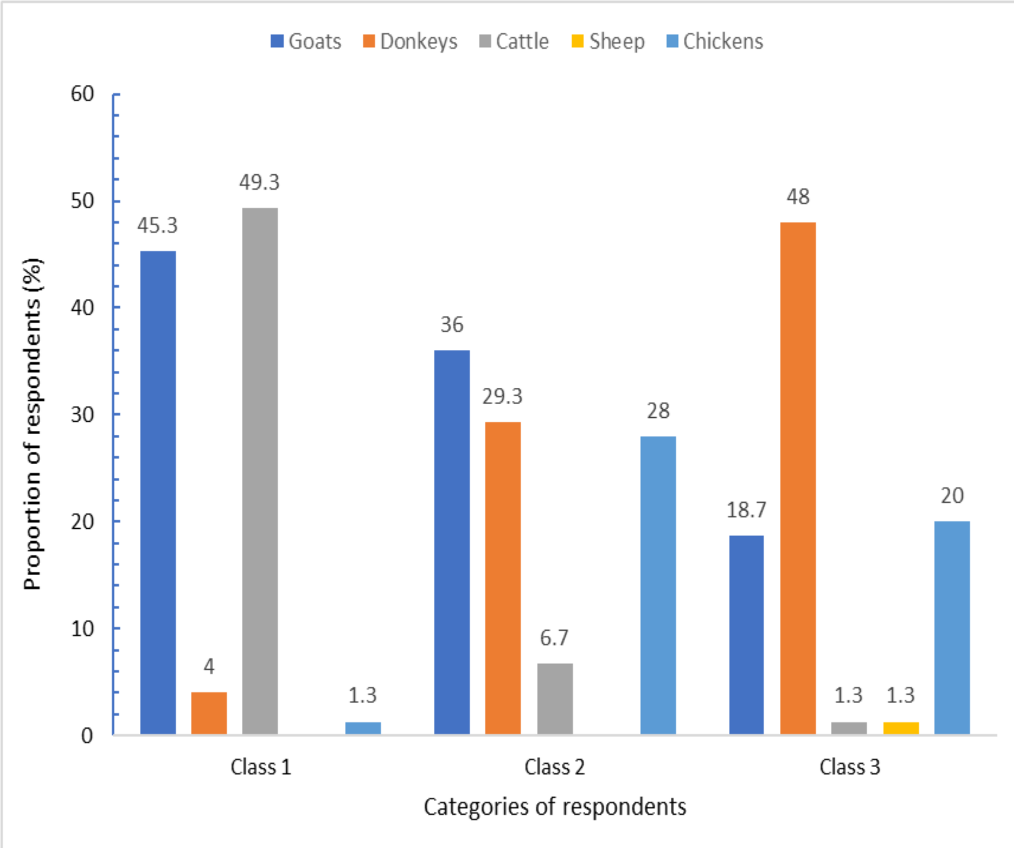


Figure 5.5: Livestock species that were supplemented in order of importance

A larger proportion of respondents (Figure 5.5) 93.4% experience feed shortages during the dry season while 6.6% said they experience the problem in summer. Livestock species supplemented by farmers, were categorized into three classes; Class 1; 45.3% had goats, 49.3% had cattle and 4% had donkeys. Class 2; 36% had goats, 29.3% had donkeys, 6.7% had cattle and 28% had chickens. Class 3; 18.7% had goats, 48% had donkeys, 1.3% had cattle and 20% had chickens. All the three classes prioritized goats, cattle and donkeys. However, classes 2 and 3 also included chickens. Goats were prioritized in classes 2 and 3 while in class 1 cattle were high priority

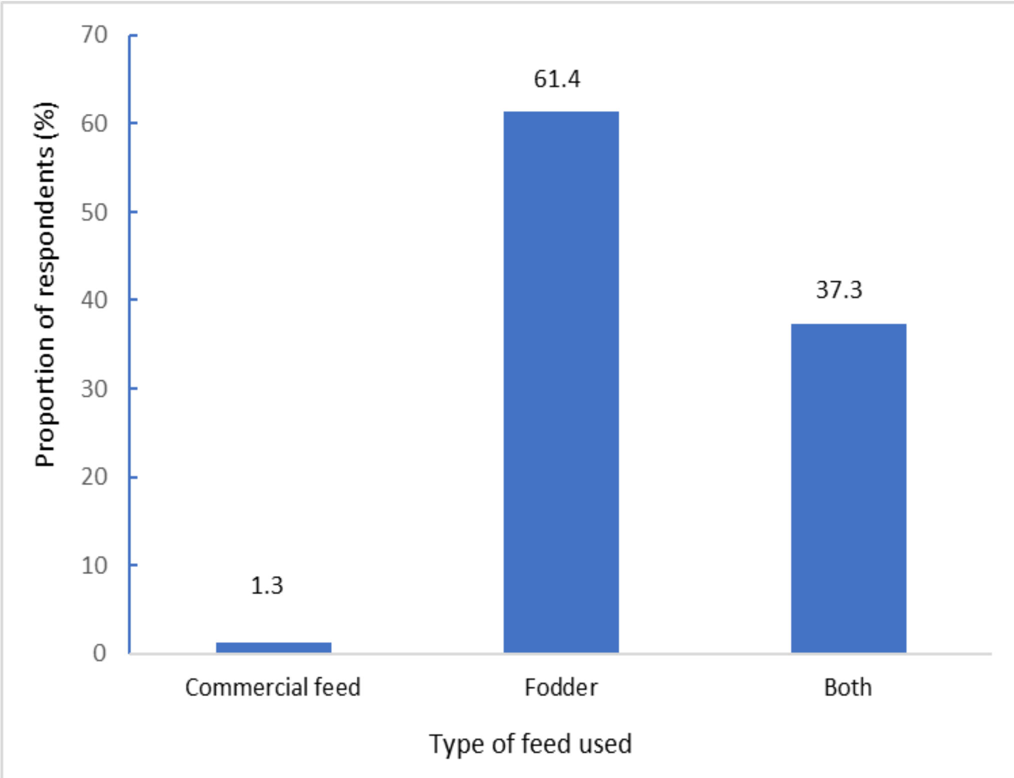


Figure 5.6: Types of feedstuffs used by farmers to supplemented livestock

Results indicate that respondents supplement livestock with both commercial feeds and fodder (Figure 5.6). However, 61.3% of respondents used fodder, 1.3% used commercial feeds while 37.3% used both fodder and commercial feeds. The supplementation period ranged between three and six months according to responses given. Respondents who supplemented animals for one to three months constituted 64% and three to six months constituted 36%. What comes out strongly from the results is that farmers supplemented livestock in the dry season, to prevent mortalities caused by starvation. Respondents constituting 93.4% said the dry season was the worst period affected by feed shortages, while those who indicated summer accounted for 6.6%. Results also indicated fodder production adoption by communal farmers in semi-arid southwestern Zimbabwe to mitigate dry season feed shortages.

Table 5.1: Facts about fodder production in semi-arid communal areas

Method of fodder preservation	Proportion of respondents (%)
Hay	86.7
Silage	13.3
Impact of fodder on livestock mortalities	
Decreased	97.3
Increased	2.7
Means of annual fodder yield	
<250kg	40.0
251 – 500kg	45.3
>500kg	14.7
Effect of fodder on milking duration	
Increased	70.7
No change	29.3

(Table 5.1) indicates that the proportion of respondents who preferred to prepare hay with their fodder constituted 86.7%, while the remainder 13.3% preferred silage. A proportion of 97.3% of respondents indicated a reduction in poverty deaths in their herds due to adoption of fodder, while only 2.7% said mortalities increased. A proportion of 40% of respondents produced an average of 250kg of fodder per year, 45.3% produced between 251 and 500kg while 14.7% produced fodder above 500kg. A proportion of 70.7% of respondents, indicated an increase in the milking period due to supplementation, while a proportion of 29.3% of respondents did not notice any change.

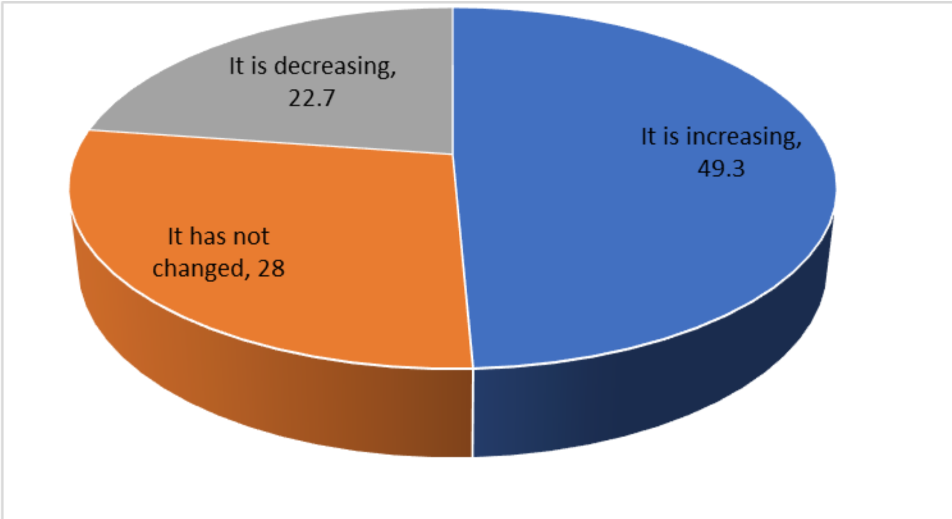


Figure 5.7: Proportions of farmers who adopted fodder production

Results of the survey showed a proportion of 49.3% of respondents indicated that the number of armers who adopted fodder production increased (Figure 5.7). However, a proportion of 28% of respondents noticed no change while 22.7% thought the number of farmers who adopted fodder production went down. A proportion of 54.7% of respondents indicated that they had shared fodder production knowledge with five farmers; A proportion of 37.3% of respondents had shared with six to ten people while 8% shared the knowledge with eleven to fifteen people.

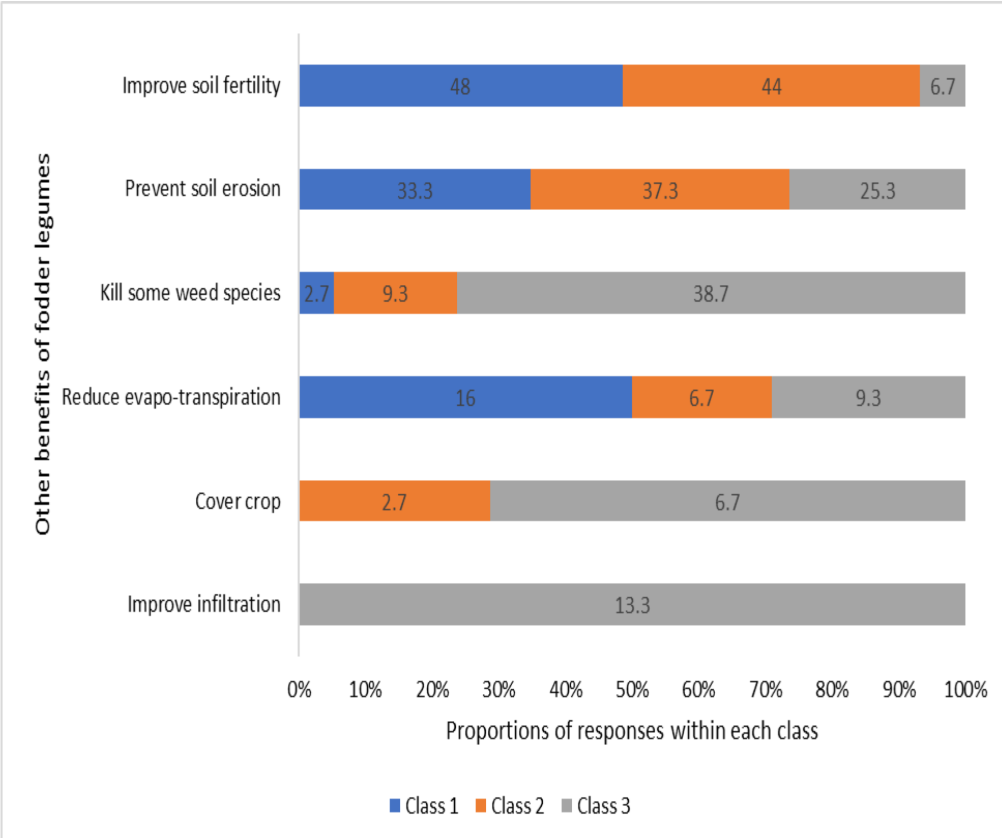


Figure 5.8: Other uses of fodder legumes besides supplementing livestock

Respondents were also asked whether fodder production had other benefits besides livestock supplementation (Figure 5.8). Responses were put into three categories; Classes 1, 2 and 3. Three responses were randomly picked; cover crop, control of certain weed species and improvement of soil fertility. For the first response Class 1 had a proportion of 2.7% while Class 3 had 6.7%. In the second response; Class 1 had 2.7%, Class 2 9.3% and Class 3; 38.7%. In the third answer; Class 1 had 48%, Class 2 44% and Class 3 6.7%. The responses show that the respondents discovered other uses of certain fodder legume crops besides livestock supplementation.

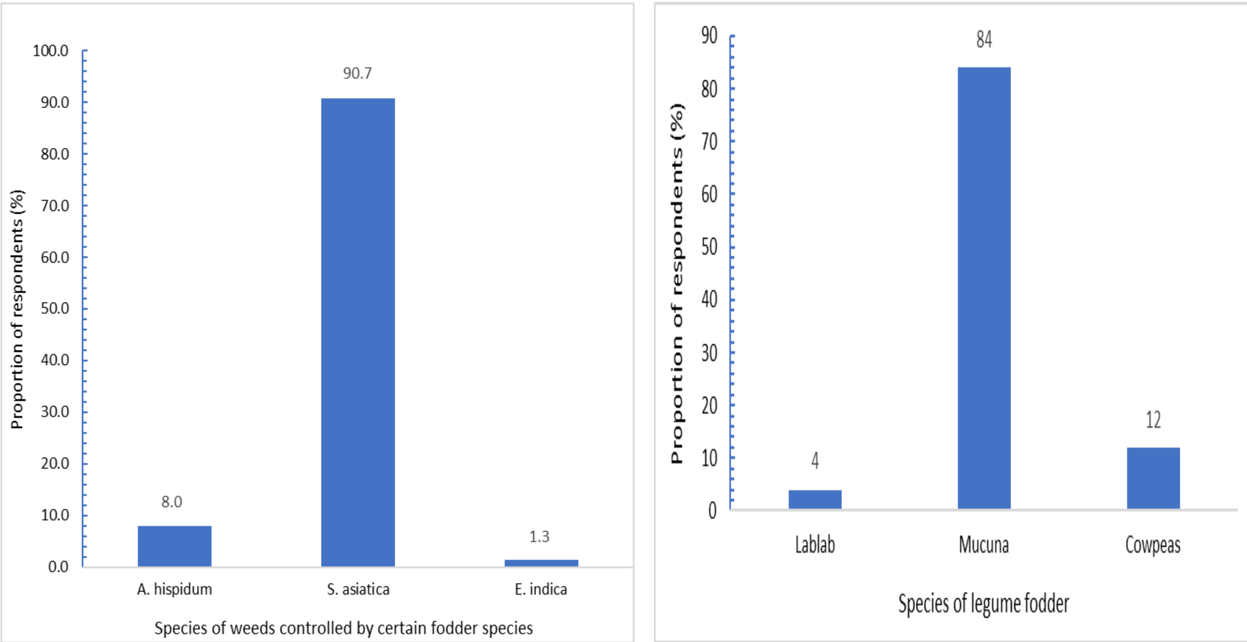


Figure 5.9: Arable weed (*Striga asiatica*) controlled by mucuna/velvet beans (*Mucuna pruriens*)

Results indicate that a proportion of 84% of respondents noticed that one of the fodder legume species controlled a certain arable weed species (Figure 5.9). Weeds have the potential to reduce yields of most crops. A proportion of 90.7% of the respondents indicated that the weed *Striga asiatica* (Witch weed) was controlled by one of the forage legume species. A proportion of 84% of the respondents indicated that the fodder legume Mucuna/Velvet beans (*Mucuna pruriens*) controls (*Striga asiatica*) Witch weed. Although the respondents' main objective for growing fodder legumes was dry season supplementation, the discovery indicated that fodder production had extra benefits.

5.7 Discussion

Semi-arid communal farmers of southwestern Zimbabwe, practice a crop-livestock system of agriculture which enables them to spread risk in their farming activities (FAO, 1992; Mugandani et al, 2012; Tessema et al., 2014). However, a bigger proportion of active farmers were elderly people (Ndhlovu, 2020). Respondents in the 51 – 60 years age group constituted a proportion of 38.7% of the respondents, while those above 61 years of age constituted 18.7% (Figure 5.1). Respondents who were actively participating in farming activities, were elderly people whose energy levels were low, which was threatening the future of farming in the area. The probable explanation for this phenomenon is that due to the proximity of the study site to Botswana and South Africa, most youths crossed borders in search of employment opportunities which left farming activities in the hands of their elderly parents and relatives (Chambers and Conway, 1992; Awono et al., 2010; Bird and Prowse, 2008). Respondents' literacy rate was high, as indicated by a proportion of 44% of respondents who went through primary education, 50.7% secondary education and 5.3% tertiary education. This factor contributed positively to the quality of work done by the respondents. Respondents indicated that they had dependents ranging between two and fourteen (Figure 5.3). This was probably a push factor for respondents to carry out agricultural activities them which enabled to sustain their livelihoods and food security.

Results indicate that although respondents were involved in a crop-livestock system of agriculture, livestock was the better agricultural option guaranteeing food security and livelihoods (FAO, 1992; Thornton et al., 2015) (Figure 5.4), because the respondents are living in a semi-arid region. Common livestock species kept by respondents included; goats, donkeys, cattle and chickens. Livestock production is dependent on rangelands which are not producing enough fodder due to over grazing (Ibanez et al., 2007), climatic conditions and many other challenges (Ebei et al., 2007; Fuhlendorf et al., 2001). Feed shortages are a major threat to livestock production, and have ripple effects on food security and livelihoods (Thornton et al., 2015). The most critical period was the dry season as indicated by a proportion of 93.4% of respondents (Figure 5.6) who experienced feed shortages during the dry season, requiring them to supplement livestock to prevent poverty deaths.

5.7.1 **Adopting fodder production as a lasting solution to annual feed shortages in semi-arid communal areas**

Semi-arid communal farmers have been experiencing feed shortages for many years which caused huge livestock losses in the past (Day et al., 2003; Ebei et al., 2007; Fan et al., 2008). Given the significance of livestock production to food security and livelihoods in semi-arid regions (FAO, 1992), it makes a whole lot of economic sense to find a lasting solution to the problem. A critical question then arises, how can the perennial the feed shortages problem be resolved permanently? One possibility to finding a long-term solution, is to buy commercial feed for dry season supplementation (Hargreaves et al., 2004). Although the solution is practicable, it will always remain a pipedream for semi-arid communal farmers, most of whom are financially constrained. Consequently, this leaves fodder production adoption as the only solution in the long term (Boller and Greene, 2010; CIAT and CGIAR, 2015). Fodder crops have many advantages over commercial feeds, which includes affordability, and this makes fodder production an ideal option for financially constrained semi-arid communal farmers (Annicchiarico, 2004; Ekepu and Tirivanhu, 2016; Kumar et al., 2022).

In addition to affordability, fodder crops readily adapt to a wide range of soil types and climatic conditions, hence they can tolerate semi-arid climatic conditions (Maass et al., 2015; Bhagawati and Paul, 2021). The crops are high yielding, palatable, nutritious and readily accepted by livestock. Adopting fodder production can become a game changer as feed shortages will be eradicated completely in semi-arid communal areas (Prakashkumar and Sreenath, 2019). Turning to fodder crops in semi-arid areas aims to solve feed shortages, by introducing high yielding and nutritious crops as livestock feed (Kumar et al., 2022). Farmers will no longer worry about feed shortages, as they watched helplessly while their livestock starved to death in the past (Day et al, 2003).

To strengthen dry season supplementation in semi-arid communal areas, fodder can be preserved in two ways; (dry form and fresh form) to enhance its utilization when the need arises (Bhandari et al., 2007; Bhagawati and Paul, 2021). Hay (Mwembe and Tavirimirwa, 2014) and silage (Fraccarolli, 2015) are feedstuffs made out of fodder materials, which communal farmers can take advantage of in semi-arid southwestern Zimbabwe. Survey results (Table 5.1), indicate that fodder production can become the panacea to feed deficits and enhance sustainability of livestock production, as micro-economies of semi-arid areas are driven by livestock production (FAO, 1992; Havstad, 2007; Thornton et al., 2015). Fodder production adoption in semi-arid communal areas is also enhanced further by the ability of some of the crops to grow under dry land production for instance; Chloris gayana, Pennisetum perpureum, *Cenchrus ciliaris*, *Mucuna pruriens* and *Lablab purpureus* to mention a few (Annicchiarico, 2004; Boller and Greene, 2010; Bhagawati and Paul, 2021). There are no special skills required for one to produce fodder crops, except the willingness to work, making them more suited for communal areas, where most of the farmers are just laymen (Figure 5.1).

5.7.2 Impact of dry season supplementation on livestock production in semi-arid communal areas

What comes out clearly is that semi-arid communal rangelands are failing to supply enough fodder-flow to livestock due to climatic conditions (Mason and Jury, 1997; O'Reagain and Scanlan, 2011) and human activities (Palmer and Bennett, 2013; Mussa et al., 2016; Norton et al., 2016). Feed shortages are frequent in semi-arid communal areas requiring interventions, which farmers are failing to execute mainly due to unavailability of the necessary resources (Kgosikoma et al., 2015). However, results of the fodder production adoption survey (Table 5.1), indicate reduction in poverty deaths due to dry season supplementation (Njauri et al., 2016; Bhagawati and Paul, 2021). This has been lacking for many years casting doubt on the future of livestock production, which is the anchor of food security and livelihoods in semi-arid communal areas. Due to the significance of livestock production to food security and livelihoods, fodder production adoption can enhance sustainability of the agricultural activity in semi-arid areas (Prakashkumar and Sreenath, 2019; Kumar et al., 2022).

Semi-arid areas of south western Zimbabwe are famous for their large herds of livestock (Ebei et al., 2007) which also feed into the national herd. The country used to fulfill beef export quotas to the lucrative European markets because of cattle from the region (Thornton et al., 2015; Mwareya, 2019). There is hope in reviving the country's livestock production industry which had been been blighted by feed deficits (Musemwa et al., 2008). In communal areas this will improve availability of food and nutrition which will ensure healthy communities. Dry season supplementation increased the milking period (Table 5.1), which is going to increase milk consumption in communal areas because it is currently low (Achchuthan and Kajananthan, 2012). Availability of surplus milk in communal areas will enhance local milk sales, and improve societies' micro-economies (Beigrezaei et al, 2022). This is a business opportunity with the potential to improve communal people's sources of income.

5.7.3 Other benefits of adopting fodder production in semi-arid communal areas

Semi-arid communal farmers practice a crop-livestock system of agriculture which helps them to spread risk in their farming activities and increases chances of food security. (Figure 5.9) shows that fodder production benefits are not limited to livestock supplementation, but also extend to crop production (Ekepu and Tirivanhu, 2016; Ginwal et al., 2019). Leguminous fodder crops such as; *Mucuna pruriens*, *Crotalaria juncea* and *Lablab purpureus* can benefit subsequent cereal crops, because of their ability to improve soil fertility through the biological nitrogen fixation process (BNF) (Ekepu and Tirivanhu, 2016. A question that comes to mind, is it supplementation that can influence fodder production adoption in semi-arid communal areas? Participants responses indicate that several reasons drive fodder production adoption in the smallholder communal sector (Figures 5.8 and 5.9). Respondents indicated that yields of subsequent cereal crops increased when used in crop rotation systems, where a cereal crop was planted after a legume crop (Shankar et al., 2022). This benefit is a real push-factor, for high fodder production adoption rate among semi-arid communal farmers. Following several years of mono-cropping systems, minerals in root zones of most crops preferred by farmers have been depleted, which causes low grain yields (Murungweni et al., 2016). The fact that fodder legume crops can fix nutrients into the soil is a probable reason why communal farmers take up fodder production (Ekepu and Tirivanhu, 2016; Visha et al., 2023). This cheaper way of fertilizing the soil is definitely preferred by communal farmers whose financial resources are low (Shankar et al., 2022).

Other benefits of fodder legume production adoption include; improving infiltration, covering crops, reducing evapo-transpiration and soil erosion (Ginwal et al., 2019). Legume fodder crops such as *Mucuna pruriens*, provide cover thereby protecting the soil from erosion and loss of soil moisture through evapo-transpiration (Ekepu and Tirivanhu, 2016). Temperatures in semi-arid areas can be quite high, however, soil moisture losses can be minimized by growing fodder legume crops (Murungweni et al., 2016; CIAT and CGIAR, 2015).

Crop yields are usually affected by weeds which cause problems including harboring pests and diseases, unfair competition for nutrients and moisture between crops and weeds, in which weeds always become the winners (Mangosho and Mupambwa, 2013). Respondents indicated that the fodder legume species *Mucuna pruriens* (Table 5.9), controlled *Striga asiatica,* a weed of economic importance. *Striga asiatica* reduces yields of most cereal crops if it is not controlled (Abdallah et al., 2015). It is probable that most respondents adopted fodder production because they also wanted to take advantage of the biological control of *S*. *asiatica* using *M*. *pruriens* especially considering that the method has no cost implications, gelling well with communal farmers who cannot afford herbicides. Most crop fields in communal areas are now infertile which can be a pull-factor to such problematic weeds as they have parasitic tendencies (Mangosho and Mupambwa, 2013).

Through monitoring and observations, the farmers discovered a cost-effective way of controlling some problematic weeds. In today’s world where people are becoming more cautious about the safety of the environment, it is commendable for the farmers to conduct their farming activities in an environmentally-friendly way (Shankar et al., 2022; Visha et al., 2023). In addition to ensuring environment safety, biological control of certain weed species is important, because calls for practice of more organic farming are getting louder, and advocating for zero-tolerance to environmental contamination with hazardous chemicals. While use of agro-chemicals helps farmers cut labour costs, the environmental damage by chemicals far outweighs the benefits. In light of this realization, use of chemicals should be minimized to ensure water bodies and waterways are free from contamination, and not affect aquatic bio-diversity. Careless utilization of hazardous substances (agro-chemicals) will always come back to haunt future generations who deserve to live in a clean environment.

5.7.4 The environmental benefit of adopting fodder production in semi-arid communal rangelands

Semi-arid communal rangelands have experienced serious degradation for a long time, which reduces species diversity and threaten rangeland sustainability (Cingolani et al., 2015). Degradation is driven by communal farmers' over reliance on rangelands for grazing and other natural resources. Changes in ecosystems and the effects of climate change are affecting semi-arid communal rangelands' stability and the effects cascade down to livestock production. One pertinent question that comes to mind is; In what way can fodder production adoption in semi-arid communal areas benefit the environment? The first step is to reduce over dependency on rangelands for livestock feed, and find an alternative source (CIAT and CGIAR, 2015; Bhagawati and Paul, 2021; Boller and Greene, 2010)). Availing feed from an alternative source to livestock can enhance recovery of grazed plants (Cowley and McCosker, 2011) as animals won't necessarily fill their guts with feed from rangelands alone. To illustrate this point; one animal eats feed equivalent to three percent of its body weight per day from the rangeland alone, but if the same animal eats two percent from the rangeland and the remainder from fodder gardens, persistence and perpetuation of certain grass species will not be affected (Bhandari et al., 2007). Rangeland degradation can be reversed by reducing grazing pressure, and allowing nature to restore what animals would have eaten (Savory and Butterfield, 2016; Sasaki et al., 2012; Tessema et al., 2014; Yates et al., 2000). Semi-arid communal rangelands are never given chance to heal independently due to several other challenges including rangeland fragmentation, high population pressure and over utilization (Reid et al., 2010; Rutherford and Powrie, 2013; Senda et al, 2020).

By allowing chance for grass species to grow, two benefits can be expected; (i) Maturity of the grass species and seed production and (ii) Replenishment of the soil seed bank which is the growth-point of future grass communities (Gamoun, 2012; Saatkamp et al, 2014; Kiss et al., 2018). All these are benefits can accrue from fodder production adoption in semi-arid communal areas where livestock production is an important agricultural activity. Reducing grazing pressure on rangelands creates a conducive environment for natural reconstruction of damaged environments. Signs of natural regeneration is indicated by species diversity and cover, both of which are affected by over grazing, which drives influx of annual grass species which are notable for low biomass production, unpalatability and inability to sustain livestock production (Sasaki et al, 2012).

Biodiversity loss is another major problem on semi-arid communal rangelands which emanated from several years of continuous and unsustainable grazing. However, fodder production adoption as an alternative source of livestock feed can enhance species diversity restoration since animals will not look up to rangelands alone for feed (Carlier et al., 2009). Naturally, animals practice selective grazing, a behaviour through which they choose and pick plants they prefer to eat. In a scenario where grazing is intensive and the period of stay long, palatable species suffer due to over grazing (Rutherford and Powrie, 2013). It is probable that due to this grazing behaviour, good forage value species were stripped from semi-arid communal rangelands (Ebei et al., 2007; Reid et al., 2010; Rutherford and Powrie, 2013). Most of such species are perennials known for their leafiness, a characteristic synonymous with high biomass production (Boller and Greene, 2010; Carlier et al., 2009). The current generation is obligated to leave a legacy for future generations, who will fill the space and expect to enjoy the same benefits, current generations are enjoying from rangelands. The time is now which the current generation should use to reverse biodiversity loss and low rangeland productivity and nurture and cox rangelands to produce more biomass, which in the long term stands to benefit livestock productivity (Savory and Butterfield, 2016; Abdelsalam et al., 2017; Anderson and Hoffman, 2007). Fodder crops have many advantages such as fast growth, high biomass yields, palatability, high nutritive value and adaptability to different habitats (Al-Hashmi, 2008; A-Karaki and Al-Hashmi, 2011; CIAT and CGIAR, 2015; Kumar et al., 2022; Bhagawati and Paul, 2021). These traits can be used to improve rangeland reconstruction and shift animals' focus on rangelands to fodder gardens for their feed requirements (Musalila et al., 2016; Ginwal et al., 2019; Bhandari et al., 2007)). As this happens, rangelands can recover and start producing more biomass in the long run, something which has been lacking for many years.

5.8 Conclusion

The dry season is a difficult time for many semi-arid communal farmers who are financially constrained to afford commercial feeds. Fodder production adoption can enhance cheap dry season feeding and prevent livestock poverty deaths. It can reduce grazing pressure on rangelands, and allow natural recovery to take place. In a way, fodder production adoption can enhance natural regeneration in semi-arid communal rangelands which are now degraded. Recover of ecosystems will take, while biodiversity will improve since plants will no longer be over grazed. Apart from providing livestock feed, some fodder legume crops such as *Mucuna pruriens* can improve soil fertility, cover crops and control the arable weed *Striga asiatica* which can reduce yields in many cereal crops. In this era, where many people are advocating for a pollution-free environment, fodder production adoption can reduce dependency on expensive and hazardous agro-chemicals, and encourage organic farming.

5.9 Recommendations

Extension Services should conduct trainings on fodder production, preservation and utilization to increase adoption in semi-arid communal areas. Validation of control of *Striga asiatica* must be conducted in semi-arid areas, where the weed is affecting yields in many cereal crops. Use of hazardous agro-chemicals should be discouraged while biological control of weeds is encouraged as this will enhance organic farming and promote a pollution free environment.

CHAPTER SIX

6 Allocation of incomes from livestock sales to family needs by farmers in a semi-arid communal area

6.1 Introduction

Livestock species such as cattle, sheep and goats are valuable live assets which significantly contribute to food security and livelihoods, in the semi-arid communal areas, where many low-income earners live (FAO, 1992; Schmidt and Pearson, 2016). Production of livestock is supported by rangelands, which don't produce low biomass onlyt, but are degraded (Ibanez et al., 2007; Gemedo-Dalle et al., 2006) and are utilized communally (Elloumi et al., 2001). The above factors threaten the future of livestock production, which is a better agricultural activity than dry land crop production which always fails, resulting in food insecurity and poor livelihoods (Phiri et al., 2019; Murungweni et al., 2016). However, technologies such as restoration of degraded rangelands (Saunders and Hobbs, 1993; Karubian and Duraes, 2009) and fodder production (CIAT and CGIAR, 2005; Mwembe and Tavirimirwa, 2020; Bhagawati and Paul, 2021; Bhandari et al., 2007), confidence in livestock production is being restored. It had been decreased by fragility of semi-arid communal rangelands and climate change effects (Eldridge et al., 2016; Deng et al., 2013; Thornton et al., 2015). Livestock production can become sustainable if farmers guard against natural resource degradation, in semi-arid communal areas (Bai and Dent, 2009). Healthy land is more productive than degraded land (Savory and Butterfield, 2016). It is able to supply fodder to animals efficiently, which can boost animal off-take, and guarantee food security. The benefit accruing from environmental stability to farmers is satisfaction of their social and economic needs (Mmbengwa et al., 2015). The benefit comes in monetary form, which farmers get after selling livestock, and satisfy family needs (Mwareya, 2019).

The significance of livestock in semi-arid communal areas

The monetary value of communal livestock is more compared to the ones in the commercial sector, when all services, products and by-products are summed (Hesse and McGregor, 2006). This disproves the general belief that animal off-take from communal rangelands is very low (Lesham and Odhiambo, 2013). The line of thinking is premised on lack of knowledge about how the communal livestock production system functions. Cattle perform many functions under communal set-up, such as providing draft-power for tillage, milk and meat for domestic consumption (Malusi et al, 2021). Smaller livestock such as goats and chickens provide petty cash, when they are sold to raise quick cash for family emergencies, while cattle are sold only when there is a crisis in the family (FAO, 1992; Barrett, 1992). Cattle are sold especially when the family needs food during a drought, or when a child needs school fees or when hospital fees and medication are required (Mwareya, 2019).

However, communal farmers are shifting gradually from their traditional way of doing things, they are drifting slowly away from a subsistence way of life to a commercial one (Coetzee et al., 2004). Past experiences show that communal farmers only sold livestock to solve family problems which required money. Nowadays they frequently sell animals at sale pens through the auction system organized monthly in their wards by Rural District Councils (Musemwa et al., 2007). Living standards in most communal setups are significantly improving as farmers frequently get money, from livestock sales through various means such as farmer-to-farmer, private buyers or the auction system which is gaining popularity among farmers (FAO, 1992).

6.2 Availability of proper livestock markets

It is not entirely true that communal farmers hold on to their animals for too long, rather the behaviour is usually driven by lack of proper livestock markets where farmers get good returns for their animals (Coetzee et al., 2004; Coetzee et al., 2004). Smallholder farmers are short-changed by middlemen most times, who usually buy animals for a song and later make huge profits from resale of the animals while the farmers sing the blues (Tavirimirwa et al., 2013). On their part, the farmers fail to form farmer groups to enable them to speak with one voice when fixing prices of their animals (Barrett, 1992). This leaves them at the mercy of middlemen who feel obliged to reap where they did not sow. Farming is a business and should be treated as such, therefore it requires communal farmers to view farming as a business, which this will make enjoy benefits from farming (Mahonya et al., 2019). The collapse of the Cold Storage Company took away the farmers' opportunity of getting good prices for their animals, like what used to happen in the past when the company was operating at full capacity (FAO, 2001).

6.3 Dealing with challenges on livestock markets in communal areas

Scrutiny of livestock markets in semi-arid communal areas points to two glaring issues; (i) Unavailability of good livestock markets in communal areas and (ii) Lack of business management and marketing skills on the part of farmers (Malusi et al., 2021). This is knowledge gap which Extension Services both public and private should fill. Non-governmental Organizations (NGO) and the government arm, the Extension Services are working flat-out to improve livelihoods and living standards in communal areas therefore, therefore, it is incumbent upon them, to conduct their work in a holistic approach (Homann and van Rooyen, 2007). Sometimes both government and NGOs donate livestock to communal farmers as a capacitation strategy, while this is commendable, the two extension entities must go a step further and train farmers on aspects of business management and marketing strategies (FAO, 2001; Malusi, 2021). Middlemen benefitting from the farmers' hard work, would find it difficult to shortchange them because they would be knowing the true value of animals they would be selling and the markets they would take their animals to (Mwayera, 2019). Competitive markets and good prices of goods are enough impetus to push farmers to invest more effort in their farming activities. Besides, the issue of low animal offtake from communal rangelands can be rectified, with more animals at their disposal, farmers are more likely to sell as many animals as y can. The frequent sale of livestock in semi-arid communal areas will positively impact on food security and livelihoods (FAO, 1992; FAO, 2001; Tavirimirwa et al., 2013).

6.3.1 **Objectives of the study**

The main objective of the study was to investigate allocation of livestock incomes to family needs in a semi-arid communal area

Specific objectives were to:

- Determine livestock species kept by semi-arid communal farmers
- Determine the species of livestock sold most by farmers and the frequency of sales
- Investigate how incomes from livestock sales are allocated to family needs
- Investigate other sources of family incomes the respondents have

6.4 Materials and methods

6.4.1 **Study site**

The study was conducted at Pelele Village, Ward 12, 21^0 30' S 28^0 30', 60 km south west of Gwanda town in Matabeleland South Province. The village has three lines; Likakeng, Mbirwane and Nyikanyoro, and 160 households distributed among the three lines. Communal farmers in this vilage, practice a crop-livestock system of agriculture, in which livestock production is the better agricultural option, because they are living in a semi-arid region. Livestock species comprise 500 cattle, 300 donkeys, 600 goats and 250 sheep, which graze on a communal rangeland. Grazing space is steadily declining as a result of fragmentation due to high demand for cropping land (Senda et al., 2020).

The site is located in agro-ecological region (AER) V, which is characterized by low and highly variable rainfall, with an annual mean below 450mm. The rainy season usually commences in November and tails off in March. The soils are sandy loams. Tree species are dominated by *Vachellia tortilis*, *Terminalia randii*, *Dichrostachys cineria*, *Lonchocarpus capassa*, *Combretum apiculatum*, *Cassia abbreviatta*, *Gymnosporia senegalensis*, *Colophospermum mopane*, *Grewia flavescens*, *Grewia monticola*, and *Gardenia volkenzii* (Kwembeya and Takawira, 2013). The dominant grass species are *Aristida barbicollis*, *Brachiaria deflexa*, *Chloris virgata*, *Eragrostis viscosa*, *Panicum novermnerve*, *Schmidtia pappophoroides* and *Tragus berteronianus* (Chippindall and Cook, 1976; Gibbs-Russell et al., 1991) and forbs such *Apium leptophylum*, *Borrreria scabra*, *Ipomoea alba*, and nutsedges *Fimbristylis disticha* and *Cyperus angolensis* (Mangosho and Mupambwa, 2013). One cactus species *Cylindriopuntia fulgida* was invasive and threated rangelands and livestock.

Procedure

A structured questionnaire was administered to 125 out of 160 farmers who stay in three lines of the village; Likakeng, Mbirwane and Nyikanyoro. The purpose of the questionnaire was to establish the species of livestock kept by farmers and whether they sell the livestock, the frequency of sales and how the money was allocated to family needs.

6.5 Data analysis

6.5.1 **Statistical model and procedure**

When the questionnaires had been completed, post coding was done, followed by double entry for data integrity checks as well as summary reports to check for inconsistencies. The next step was to carry out descriptive statistics, frequencies, measures of central tendency and dispersion [variability]. Cross tabulations were carried out to test correlation between two variables.

6.6 RESULTS

A larger proportion of respondents was in age groups above 40 years as show by 25% of respondents in the 41 – 50 years age group; 35% in the 51 – 60 years and 22.5% above 61 years (Figure 6.1). Of great concern was old people whose energy levels are low were the ones actively participating in agriculture. This was a threat to the future of agriculture in the area. Respondents below the age of 40 years were very few, which showed younger people’s lack of interest in agricultural activities. It is probable that instead of engaging in farming, they go to look for employment opportunities in neighboring countries such as Botswana and South Africa due to the proximity of the study site to those countries. However, it is interesting to note that despite crossing borders to look for employment opportunities in neighboring countries, the youths still go on to work as farm hands in those countries, despite shunning the same jobs back home (ZIMSTAT, 2018). The reason for this kind of behaviour by the youths is not known.

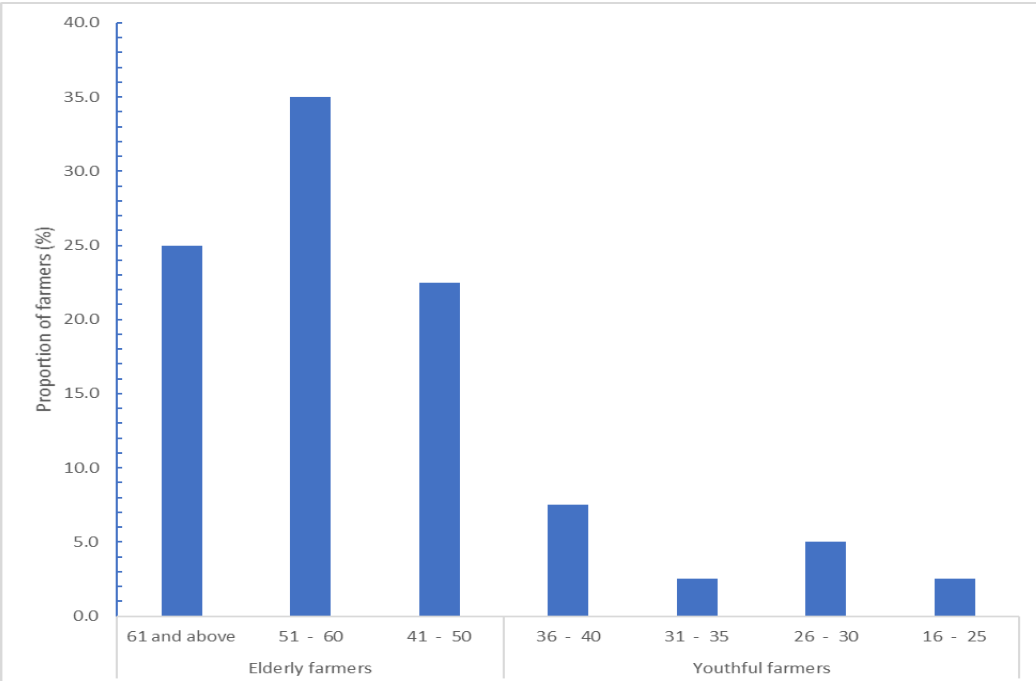


Figure 6.1: Age groups of respondents

Results of the resource allocation survey (Figure 6.1) indicated 45% of respondents being females and 55% being males. There was male dominancy in agricultural activities in community, which was a little surprising, considering that females are usually the ones dominating in agricultural activities in rural areas, because their male counterparts would be employed elsewhere. However, it is important in this case to note that most farmers are elderly people, which could be probable that a greater proportion of respondents were pensioners.

Table 6.1: Demographic information about the respondents

Gender of respondents	**Proportion (%)**
Females	45%
Males	55%
Highest level of education of respondents	
Never went to school	10%
Primary education	25%
Secondary education	50%
Tertiary education	15%
Number of years respondent has farmed in the area	
Less than 10 years	27.5%
Above 10 years	72.5%
Number of dependents	
2 – 5 dependents	57.5%
5 – 10 dependents	37.5%
11 – 16 dependents	5%

A proportion of 10% of respondents had never attended school, 25% attended primary education, 50% attended secondary education and 15% attained tertiary education (Table 6.1). Out of all respondents in the survey, 27.5% indicated that they had been staying in the area for less than ten years, while 72.5% had stayed in the area for more than ten years. Results also indicated that 57.5% had 2 – 5 dependents, 37.5% having 5 – 10 and 5% having 11 – 16 dependents. This was probably the reason why the respondents were involved in agricultural activities since they were obliged to provide for their dependents. Besides, Zimbabwe economy is agro-based, agriculture is a source of livelihoods and food security for people staying in rural communities.

Table 6.2: Number of 50kg bags of grain harvested during good and bad seasons

Season	Bags of grain harvested (50kg)	Proportion of respondents
Good	>21	50%
	16 – 20	30%
	11 – 15	10%
	5 – 10	10%
Bad	0	2.5%
	<3	27.5%
	<5	30%
	5 – 10	40%

Since the respondents were involved in a crop-livestock system of agriculture, they sometimes harvested grain from their fields (Table 6.2). However, good harvests were far in-between due to frequent droughts which caused crop failures. Results indicated that in a good year, 50% of respondents harvested above twenty-one 50kg bags of grain, 30% harvested sixteen to twenty, 10% harvested eleven to fifteen and another 10% also harvested five to ten bags of grain. However, in a bad year, 2.5% of the respondents indicated they harvested nothing, 27.5% harvested less than three 50kg bags, 30% harvested less than five bags while 40% harvested five to ten bags. This clearly demonstrates that dry land crop farming in semi-arid areas is highly unreliable. Due to this reason, respondents spread risk by practicing a crop - livestock system of agriculture, with the later providing them a safety-net against food insecurity.

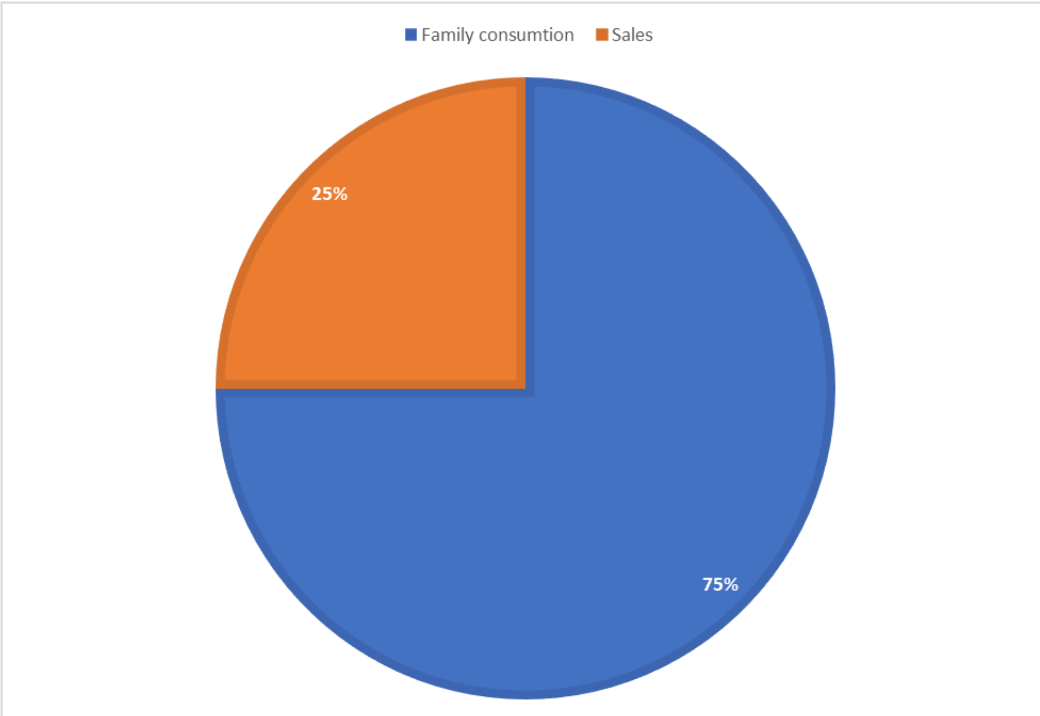


Figure 6.2: Proportions of respondents indicating reason for producing grain

Survey results indicated that 75% of respondents produced grain for family consumption (Figure 6.2), while 25 produced it for sale. The responses demonstrate that the respondents are living a subsistence way of life, where produce from their agricultural activities is for domestic consumption.

Table 6.3: Methods used by respondents to sell grain

Method of sale of grain	Proportion of respondents
Contract farming	2.5%
Private buyers	45%
Grain Marketing Board (GMB)	52.5%

Results of the allocation of resources to family needs survey (Table 6.3) shows 52.5% of respondents sold grain to the Grain Marketing Board (GMB), 45% sold it to private buyers and 2,5% were in contract farming. The GMB is a quasi-government parastatal, responsible for distributing farming inputs to farmers and buying produce from them. Those farmers who receive such inputs are required by law to sell their produce to the parastatal, while farmers who breach the agreement are liable to prosecution.

Farmers who sold produce to private buyers usually conducted farmer-to-farmer sales, which did not pay well as sales are slow and far-n-between. Besides, during good years grain is hard to sell as everyone else would be having something in store. This method of selling is only good during bad years as most people would be looking for grain everywhere possible to feed their families. Contract farming is also not reliable, farmers are sometimes duped by unscrupulous companies or individuals who collected grain from them with promises of paying later but ended up disappearing for good.

Table 6.4: Crops grown by respondents

Duration respondent has farmed in the area	Type of crops grown	Proportion of respondents
<10 years	Maize	33.3%
	Groundnuts	21.2%
	Sorghum	18.2%
	Bambara nuts	9.1%
>10 years	Maize	33.3%
	Groundnuts	23.0%
	Cowpeas	21.8%
	Sorghum	13.8%
	Bambara nuts	4.6%
	Pearl millet	3.4%

Respondents were categorized under two classes (Table 6.4), those who had been farming in the area for less than 10 years, and those that have been farming in the area for more than 10 years. In the category of farmers who have been in the area for less than ten years, 33.3% of respondents grew maize, 21.2% grew groundnuts, 18.2% grew sorghum and 9.1% grew Bambara nuts.

In the second category of respondents who have been farming in the area for more than ten years, 33.3% grew maize, 23.0% grew groundnuts, 21.8% grew cowpeas, 13.8% sorghum and 3.4% grew pearl millet. Except for maize, all the crops were suitable for semi-arid areas.

Table 6.5: Livestock species kept by the two categories of respondents

Duration respondent has farmed in the area	Species of livestock kept by respondents	Proportion of respondents
<10 years	Cattle	30.3%
	Goats	33.3%
	Sheep	3.0%
	Donkeys	3.0%
	Pigs	3.0%
	Chickens	27.3%
>10 years	Cattle	31.0%
	Goats	31.0%
	Sheep	10.3%
	Donkeys	3.4%
	Chickens	24.1%

Respondents were categorized under two classes (Table 6.5), those who had been farming in the area for less than 10 years, and those that have been farming in the area for more than 10 years. In the category of farmers who have been in the area for less than ten years, 33.3% of respondents kept goats, 30.3% kept cattle, 27.3% kept chickens while sheep, donkeys and pigs there were 3% for each livestock species. In the second category of respondents who have been farming in the area for more than ten years, 31.0% of them indicated that they kept cattle, another 31.0% kept goats, 24.1% kept chickens. 10.3% kept sheep and 3.4% kept donkeys. The livestock species play an important role in the crop-livestock system of agriculture practiced by the farmers which help to sustain food security and livelihoods. It is important to note that in a communal setup, livestock perform many functions which all contribute to livelihoods to the rural communities, some of which include animal draft-power from cattle and donkeys. The functions help to strengthen food security in households.

Table 6.6: Livestock species usually sold by respondents

Duration respondent has farmed in the area	Livestock species usually sold	Proportions of respondents
<10 years	Goats	33.3%
	Cattle	30.3%
	Chickens	27.3%
	Sheep	3.0%
	Donkeys	3.0%
	Pigs	3.0%
>10 years	Cattle	31.0%
	Goats	27.6%
	Chickens	27.6%
	Sheep	9.2%
	Donkeys	4.6%

Respondents indicated that they sold livestock once in a while in order to satisfy family needs (Table 6.6). In the respondents who have been farming in the area for a period below ten years 33.3% sold goats, 30.3% sold cattle, 27.3% sold chickens while there were 3.0% each for sheep, donkeys and pigs. In the second category where farmers had stayed in the area for over ten years 31.0% sold cattle, 27,6% goats, 27.6% sold chickens, 9.2% sold sheep and 4.6% sold donkeys. What comes out strongly from the results is that respondents sell livestock at one time or another to satisfy family needs. However, respondents in the second category sold more cattle (31.0%) than those sold by respondents in the first category (30.3%). It is probable that this happened because respondents in the second category were more established than the ones in the first category, hence they kept larger herds of cattle giving an allowance for higher cattle off-take. Respondents in the first category indicated that they sold more goats than those in the second category. The proportion of respondents who sold chickens is the same in both categories (27.3%) probably because chickens are easier to sell without family members consulting each other first. In addition to being easy to dispose of, chickens breed fast thus their numbers increase rapidly availing bigger numbers of disposable birds.

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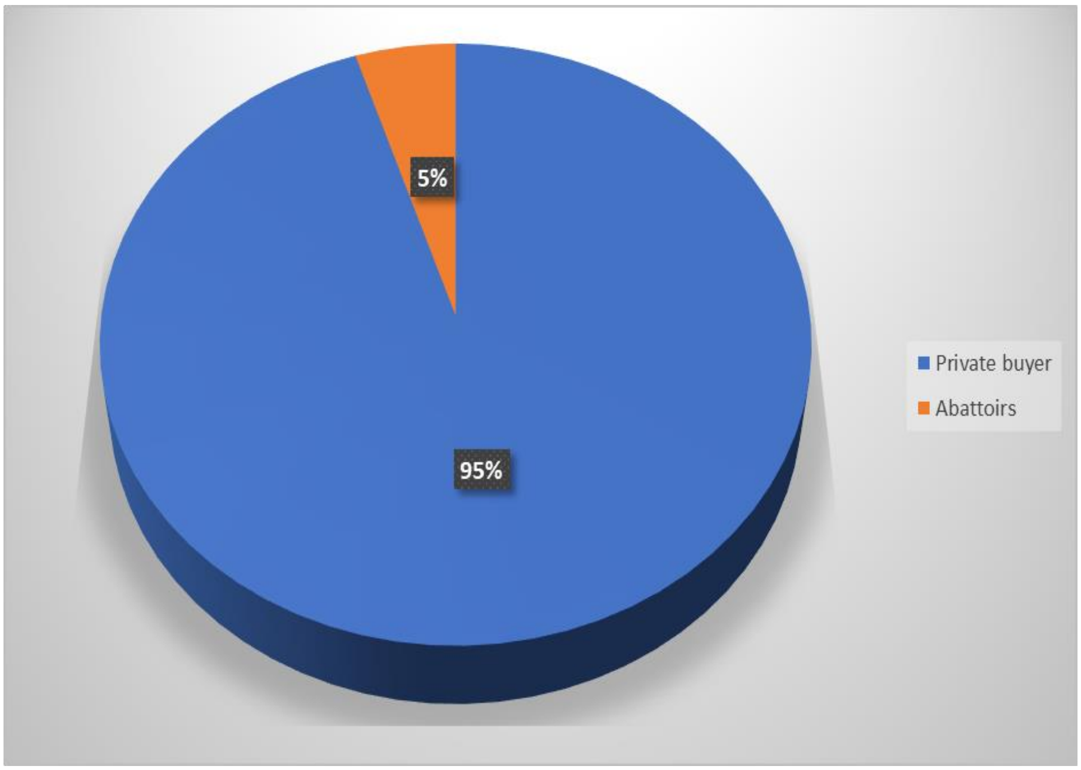

Figure 6.3: Major buyers of livestock kept by respondents

Results indicated that respondents had two possible markets (Figure 6.3), 95% of respondents sold livestock to private buyers and only 5% sold their livestock to abattoirs. Private buyers usually include farmer-to-farmer sales or sales to individuals living outside the area. Middlemen are also included in this group of buyers, and while respondents manage to sell livestock through this type of market, they cannot make much money because the market is open to bargaining. The limitation of this type of market is that if the respondent is not good at bargaining, they cannot get a price for their animal and vice versa

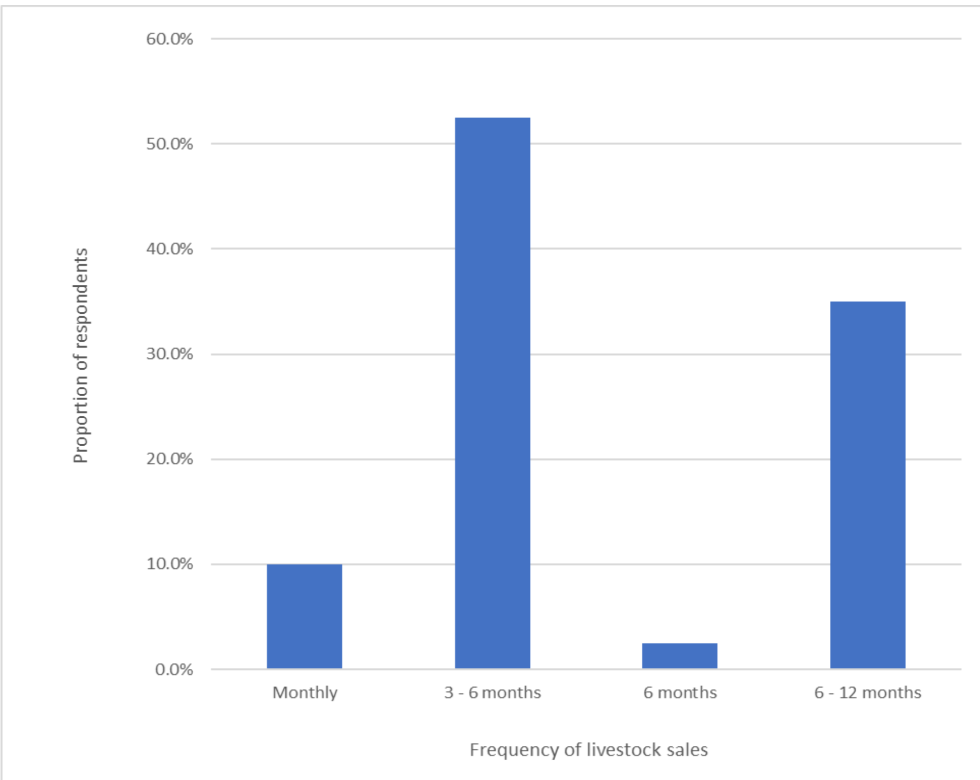

Figure 6.4: Frequencies of livestock sales

Results showed that respondents sold livestock once in a while (Figure 6.4); 10.0% sold livestock every month, 52.5% sold livestock every three to six months, 2.5% sold livestock every six months while 35.0% sold livestock every six to twelve months. The frequencies of sales show that livestock are important live assets in sustaining food security and livelihoods of communal people living in semi-arid areas. Results also show that more livestock sales take place in two periods during the year; three to six months (52.5%) and six to twelve months

(35%) while the other two periods had less sales of 10.0% for monthly sales and 2.5% for every six months.

Results showed that livestock sales were driven by family needs as indicated by proportions of respondents for each reason Figure 6.5; 12.5% sell livestock when the family needs money, 5% sell livestock when they want to buy food, 7,5% sell livestock to raise school fees while 75.0% sold livestock for all the above reasons. What comes out strongly is that livestock are a store of wealth, waiting to be used when the family is in need of money.

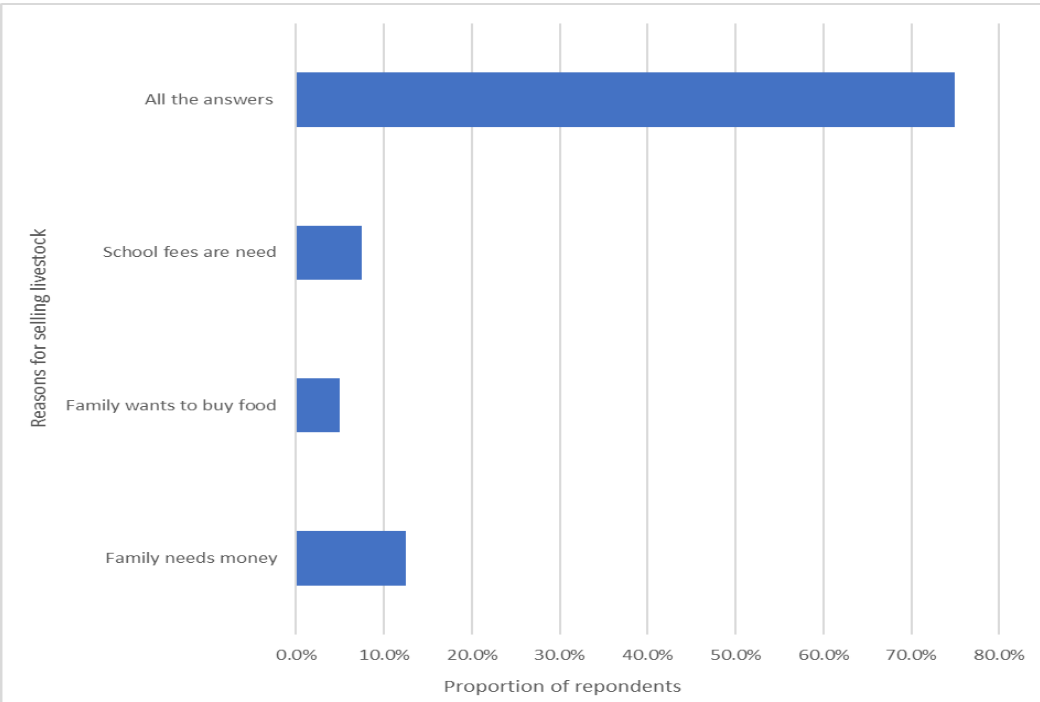

Figure 6.5: Respondents' reasons for selling livestock

Results showed that livestock sales were driven by family needs as indicated by proportions of respondents for each reason (Figure 6.5); 12.5% sold livestock when the family needed money, 5% sold livestock when they wanted to buy food, 7,5% sold livestock to raise school fees while 75.0% sold livestock for all the above reasons. What comes out strongly is that livestock are a store of wealth, waiting to be used when the family needed money.

Table 6.6: Proportions of allocation of livestock incomes to family needs

Duration respondent has farmed in the area	Family needs	Proportion of respondents
<10 years	Food	33.3%
	Medicines	33.3%
	School fees	27.3%
	Restocking	6.1%
>10 years	Food	19.8%
	Medicines	32.6%
	School fees	27.9%
	Restocking	17.4%
	Savings	2.3%

(Table 6.6) indicates the items respondents spend their money from livestock sales on. Respondents were categorized under two classes; those farming in the area for less than ten years and those farming in the area for more than ten years. In the class of respondents who farmed in the area for less than ten years 33.3% spent their money on food, 33.3% on medicines, 27.3% on school fees and 6.1% on restocking. The class of respondents who farmed in the area for more than ten years; 19.8% spend their money on food, 32.6% on medicines, 27.9% on school fees and 17.4% on restocking.

(Table 6.6) shows the differences in proportions in allocations of livestock sales incomes for food and restocking between the two classes of respondents. The class of respondents who have been in the area for more than ten years had a lower proportion for food than those who have less than ten years. However, on restocking, the respondents who have been farming in the area for more than ten years constituted 17.4% compared to 6.1% for respondents who have been farming in the area for less than ten years. The category with respondents who have been farming in the area for more than ten years, 2.3% of the respondents also indicated that they saved some of their incomes while the other class not mention savings. Both classes had almost similar proportions of respondents on who allocated resources to medicines and school fees.

Table 6.7: Other sources of incomes for the respondents

Duration respondent has farmed in the area	Sources of incomes	Proportions of respondents
<10 years	Remittances	21.2%
	Crop sales	18.2%
	Cattle sales	6.1%
	Goat sales	9.1%
	Piece jobs	12.1%
	Monthly salaries	18.2%
	Pensions	15.2%
>10 years	Remittances	13.8%
	Crop sales	23.0%
	Cattle sales	25.3%
	Goat sales	8.0%
	Piece jobs	8.0%
	Monthly salaries	6.9%
	Pensions	14.9%

Results showed respondents' sources of incomes (Table 6.7) categorized under two classes; those that have been farming in the area for less than ten years and those that have been farming in the area for more than ten years. Respondents in the class of farmers who have been farming in the area for less than ten years, indicated 21.2% receiving remittances, 18.2% got money from crop sales, 6.1% cattle sales, 9.1% goat sales, 12,1% piece jobs, 18.2% monthly salaries and 15.2% pensions.

In the category of respondents who had been farming in the area for over ten years, proportions of respondents were as follows; remittances 13.8%, crops sales 23.0%, cattle sales 25.3%, goat sales 8.0%, piece jobs 8.0%, monthly salaries 6.9% and pensions 14.9%. The second class of respondents had higher proportions for crop sales 23.0%, cattle sales 25.3% but had lower proportions on monthly salaries 6.9%, piece jobs 8.0% and pensions 14.9% compared to the group of respondents who had been in the area for less than ten years. It is probable that respondents who had been farming in the area for more than ten years were more established, hence they relied more on agricultural activities for their livelihoods.

It is probable that the category that had been farming in the area for more than ten years has respondents who settled well in the area hence they are benefitting from their agricultural activities. The category of new comers is still settling in, and because of that reason, they depend more on sources of income such as remittances 2.2%, monthly salaries 18.2% and pensions 15.2%.

6.7 DISCUSSION

The crop-livestock system of agriculture practiced in semi-arid communal areas of south western Zimbabwe is dominated by farmers who are above forty years of age (Figure 6.1). Few youths are into farming, which is not good for the future of farming in the area. A question that arises is why are youths in the area not interested in agricultural activities? It is probable that since the communal agricultural system is not well developed due to lack of financial resources to buy modern equipment, youths find farming unattractive (Chimonyo et al., 1999; FAO, 2001; Chidoko and Zhou, 2012). Instead they cross borders into neighbouring Botswana and South Africa, to look for employment as a coping strategy, where they incidentally get employed in farms (ZIMSTAT, 2018; Bird and Prowse, 2008).

Results show a proportion of 45% of respondents being for females, while 55% were males (Table 6.1), which indicating male dominancy in farming activities, despite the general belief that females make up the majority of farmers in rural communities (IFAD, 2018). Respondents showed 10% never went to school, 25% attended primary education, 50% attended secondary education and 15% attained tertiary education. The respondents were categorized under two classes; those that have farmed in the area for not more than ten years constituted 27.5% and those that have farmed in the area for more than ten years were 72,5%. Results of the survey indicate that the majority of respondents were more established farmers. Respondents had dependents; two to five 57.5%, 6 to ten 37.5% and 11 to sixteen 5%. It is probable that having dependents was a push factor for respondents to farm, so that they could provide for them (Fan et al., 2008). However, it is commonly known that farming is a source of livelihood for many rural people (Homann and van Rooyen, 2007).

Results also showed that respondents grew crops mainly for domestic consumption as indicated by 75% of respondents, 25% sold their produce (Figure 6.2). Crops grown by respondents who were categorized under two classes (Table 6.4); those that have farmed in the area for less than ten years; Maize 33.3%, Sorghum 18.2%, Ground nuts 21.2% and Bambara nuts 9.1%. Respondents who have farming in the area for more than ten years; Maize 33.3%, Sorghum 13.8%, Pearl millet 3.4%, Ground nuts 23.0%, Cowpeas 21.8% and Bambara nuts 4.6%. It is surprising however, that despite farming in semi-arid areas where rainfall is low and highly variable, the respondents still preferred maize as indicated by 33.3% of respondents from each group. However, respondents in the category of farmers who have farmed in the area for more than ten years had a wider selection of drought tolerant crops (Murungweni et al., 2016; Phiri et al., 2019). This is indicated by crops such as; Sorghum 13.8%, Pearl millet 3.4%, Ground nuts

23.0%, Cowpeas 21.8% and Bambara nuts 4.6%. The crops commonly referred to as Traditional Grains are drought tolerant and suited to semi-arid areas (Homann-Kee Tui et al., 2013). Since the respondents are farming in a semi-arid area, incidents of crop failures are high as indicated by 60% who harvested between zero and five 50kg bags of grain and 40% who harvested between five and ten 50kg bags of grain. In good years, which are far in-between a combined figure of 50% of respondents harvested between five and twenty 50kg bags of grain and another 50% of respondents harvested above twenty-one 50kg bags of grain. The figures are not surprising considering that they do mostly small grains which adapt well to the harsh weather conditions of semi-arid regions (Phiri et al., 2019). Respondents sold grain to private buyers as indicated by a proportion of 45% of respondents, 52.5% sold grain to the government owned parastatal; Grain Marketing Board (GMB) while 2.5% of respondents did contract farming. The low percentage of respondents who did contract farming can be attributed to the system's unreliability (Mazwi et al., 2018). While this system is be good, it has its own short comings such as short-changing farmers by unscrupulous dealers.

6.7.1 **Spreading the risk in farming activities**

Semi-arid communal farmers spread risk in their farming activities by keeping livestock (FAO, 2001) (Table 6.5). Respondents were categorized under two classes; those who have farmed in the area for less than ten years and those who have farmed in the area for more than ten years. In the first category 30.3% kept cattle, 33.3% kept goats, 3% kept sheep, 3% kept donkeys and 27.3% kept chickens. In the second category; 31.0% kept cattle, 31.0% kept goats, 10.3% kept sheep, 3.4% kept donkeys and 24.1% kept chickens. The results further confirm that semi-arid communal farmers are involved in a crop-livestock system of agriculture (Homann and van Rooyen, 2007; Homann-Kee Tui et al., 2013). While crops are more sensitive to dry spells, livestock are tolerant hence, they are the flagship of food security and livelihoods in the areas (Tavirimirwa et al., 2013; Thornton et al., 2015). Between the two categories of respondents (Table 6.6), those in the first category sold more goats as shown by 33.3% of the respondents, 30.3% cattle, 27.3% chickens while sheep, donkeys and pigs had 3% each. However, in the category of respondents who have been farming in the area for more than ten years, results indicate that they sold more cattle 31.0%, goats 27.6% chickens 27.6%, sheep 9.2% and donkeys 4.6% (Tavirimirwa et al, 2013). One possible explanation for the higher percentage of respondents who sold cattle in the category, is that they were more established hence, they had more cattle to sell (Mwayera, 2019). Most respondents, 95% sold livestock to private buyers (Figure 6.3), while 5% sold to abattoirs. Although most respondents chose to sell livestock to private buyers, the market was prone to irregular marketing practices, resulting in respondents losing money to middlemen (Musemwa et al., 2008). Results also showed a proportion of 52.5% preferring to sell livestock every three to six months, 35% every six to twelve months (Figure 6.4). The other frequencies had lower proportions as indicated by 10% who sold livestock monthly and 2.5% who sold livestock every six months.

Communal sector livestock are a store of wealth waiting to be exchanged for money when the need arises (Ebei et al., 2007; Mwayera,2019). While there were similarities in the items which respondents allocated money from livestock sales to, between two farmers' categories (Figure 6.7), there were differences in the proportions of respondents as indicated by respondents who have been farming in the area for less than ten years; food 33.3%, medicines 33.3%, school fees 27.3% and restocking 6.1%. Respondents who have farmed for more than ten years showed that 19.8% spent money of food, 32.6% on medications, 27.9% on school fees, 17.4% on restocking and 2.3% on savings. One point of interest is that respondents who have been farming in the area for more than ten years allocated 17.4% of the resources to restocking (Thornton et al., 2015) and 2.3% to savings. Respondents in the second category probably wanted to keep livestock production sustainable, hence the thought of restocking and saving for a rainy day (Achchutan and Kajananthan, 2012). Semi-arid regions are prone to droughts, and as such feed shortages are quite common, some of which caused heavy livestock mortalities (Day et al., 2003). Respondents in the category who have farmed in the area for a period exceeding ten years, use restocking as an adaptation strategy, considering poverty deaths which occur in the dry season once in a while or during a drought (Hargreaves et al., 2004). However, it is not clear why respondents in the first category reserved very little for restocking as shown by 6.1% of the respondents (Figure 6.7), and never saved for a rainy day.

What comes out clearly from the respondents is that there are three major items which both groups spent incomes from livestock sales. These include; food, medication and school fees, as indicated by both categories of respondents, who have presented significant percentages for the items (Figure 6.7). The allocation of more resources to food as indicated by both categories of respondents justifies why livestock production in semi-arid communal areas is associated with food security and livelihoods (FAO, 1992; Homann and van Rooyen, 2007; Thornton et al., 2015). The larger percentages of financial resources allocated to medication for both groups are probably pushed up by the cost of living which is generally high in the country, due to unfavorable prevailing economic conditions. Over the years, the country has been battling with runaway inflation, which triggers high prices of goods and services (ZIMSTAT, 2018). While some of the respondents in both categories indicated receiving monthly salaries (Table 6.8), it is important to note that most people in semi-arid communal areas are not gainfully employed, hence they look up to agriculture as a source livelihood (FAO, 1992; FAO, 2001). The agricultural activities they do must take care of their family needs.

6.7.2 Other sources of income of the respondents

Although respondents indicated getting incomes from agricultural activities, which confirms that agriculture is a source of food security and livelihoods, they also had other sources of incomes (Adam et al., 2013). It is probable that the other sources of incomes are safety-nets safeguarding the respondents against the unpredictable forces of nature (Abtew et al., 2012). Natural disasters have the potential to cause failure in farming activities, especially considering that the respondents are in semi-arid areas where climatic conditions are not conducive for agriculture (Mugandani et al., 2012; Thornton et al., 2015). (Table 6.8) indicates that respondents who have been farming in the area for less than ten years also got incomes from non-agriculturally related sources (Adam et al., 2013). A proportion of 21.2% received remittances, 12.1% got incomes from piece jobs, 18.2% received monthly salaries while 15.2% received incomes from pension funds. In the category of respondents who have been farming in the area for more than ten years, 13.8% received remittances, 8.0% got incomes from piece jobs, 6.0% received money from salaries and 14.9% received money from pension funds. Considering the age groups of the respondents (Figure 6.1), it is probable that some of the respondents are pensioners.

6.8 CONCLUSION

Livestock production in the semi-arid communal areas, is an important agricultural activity, which contributes significantly to food security and livelihoods. Animals are kept in lieu of money and are sold when need arises, to satisfy family needs such as food, school fees, medication and in some cases restocking and savings. Although livestock sales are far in-between, semi-arid communal farmers sell livestock at one point or another, through various means, when money is needed in the family. Livestock production also complements crop production which is not reliable due to high incidents of droughts.

6.9 RECOMMENDATIONS

Effort must be made to increase livestock numbers kept by communal farmers to avail adequate numbers for offtake at any given time. Adaptation interventions such as restocking and fodder production must be adopted to strengthen livestock production. The genetics of livestock species kept in communal areas must be improved with superior breeds to enable farmers to make profits when they sell animals. Development agents such as Public and Private Extension Services need to work hard to develop a good market for the farmers' livestock.

7 CHAPTER SEVEN SUMMARY AND CONCLUSIONS

7.1 Background

Semi-arid communal rangelands are an important matrix in the livestock production value-chain and a good source of cheap livestock feed (Abate et al., 2012). Livestock production is a better agricultural option, in the crop-livestock agriculture system practiced in semi-arid communal areas, which offers better chances of food security than crop production which usually fails due to frequent droughts (Tavirimirwa et al., 2013; Phiri et al., 2019). The agricultural activity contributes significantly to food security and livelihoods of poorly resourced semi-arid communal people (Table 6.7) (FAO, 1992; Barrett, 1992). However, sustainability of livestock production in semi-arid areas is affected by low rangeland productivity (Steinfeld et al., 2006).

Semi-arid communal rangelands are constrained by several challenges both biotic and abiotic. Their future is also threatened by rangeland fragmentation (Senda et al., 2020) which is driven by high demand for agricultural land, while grazing pressure, high population pressure and over grazing are further complicating the problem. The net effect of the myriad problems on semi-arid communal rangelands summed, up is serious degradation, which further lowers rangeland productivity (Young et al., 2013).

With climate change adding complexity to existing problems, livestock production's future on semi-arid communal rangelands is uncertain. (Wigley-Coetsee and Staver, 2020) The uncertainty has ripple effects on food security and livelihoods which are dependent on livestock production (FAO, 1992; Thornton et al, 2015). To avert future food insecurity, due to low livestock productivity, rangeland degradation needs to be reversed through rehabilitation of semi-arid communal rangelands, which are the basis of livestock production (UNFCCC, 2008; Scholz, 1995). Rangeland productivity can be increased through three possible interventions; (i) Rebuilding the rangelands through manual reseeding (Kiss et al., 2018; Vandvik et al., 2016) (ii) Reseeding the rangelands through livestock (Savory and Butterfield, 2016; Aboling et al,, 2008; Gokbulak, 2006) and (iii) Fodder production adoption to reduce grazing pressure on the rangelands (CIAT and CGIAR, 2015; Bhagawati and Paul, 2021; Kumar et al., 2022). Several benefits (Table 3.2) such as; species diversity, ecosystems restoration and increased biomass production can accrue through rangeland reconstruction, which will avail more feed to grazers (Shinde and Malshe, 2015; Tessema et al., 2011). This is possible in that healthy land is more productive than unhealthy one (de Groot et al., 1992; Cowley and McCosker, 2011). As proven by results of the two seed dispersion experiments, biomass production increased at all treatments; which boosted rangeland productivity, thereby guaranteeing sustainability of extensive livestock production in semi-arid communal areas (Sagario et al, 2020; Loydi et al, 2012).

7.2 The benefits of reseeding

One major negative impact of degradation is soil seed bank depletion. The soil seed bank is the growth point of ecosystems and habitats, which enhances species perpetuation and persistence (Babai and Molnarc, 2013). While, (Figure 3.2) showed low seedling counts on the Control plot, they increased at treatments or reseeded plots. This indicates effectiveness of healthy soil seed banks on species regeneration (Manske, 2005; Kiss et al., 2018). The benefit does not end at boosting the soil seed bank, but also extends to species diversity and forage value. (Figures 3.6; 3.7 and 3.8), which indicated an increase in palatable perennial grass species, averaging eight species at treatment compared to the Control plot (Figure 3.9), which had only two palatable perennial grass species. Palatable perennial grass species are famous because of their leafiness, a characteristic that favours high biomass production which avails more livestock feed (Holechek et al., 2004; Day et al., 1997). Species diversity and grazing value improvement is needed in semi-arid communal rangelands, where mismanagement altered species to predominantly unpalatable annuals such as *Aristida barbicollis*, *Brachiaria deflexa* and *Tragus berteronianus* which apart from producing low biomass, cannot support livestock production (Gamoun et al., 2014; Gemedo-Dalle et al., 2006). While the dominant grass species on the rangeland was *Aristida barbicollis* an unpalatable annual, reseeding altered that, and *Heteropogon contortus* became dominant, (Table 3,2) and (Figure 3.5).

Biomass production on reseeded plots increased (Table 3.3), which resulted in mean biomass trebling (0.285^{a}t/ha) at Treatment SRB, and doubling at treatment SB (0.254^{ab}t/ha). What comes out clearly is that reseeding causes two things to happen on a degraded rangeland; (i) Species diversity increases and (ii) Biomass production increases (Petermann and Buzhdygan, 2021; Buzhdygan et al., 2020). Grass species increased in that treatments as indicated by more perennials with good grazing value (Gibbs Russell et al., 1991). Perennial grass species such as *Heteropogon contortus*, *Urochloa mosambicensis*, *Eragrostis trichophora*, *Eragrostis rigidior*, *Panicum* maximum and *Eragrostis superba* were introduced through reseeding. One advantage of perennial grass species is their ability to perpetuate by tillers (Brown and Bugg, 2001). Reseeding is a tool with great potential to address degradation on semi-arid communal rangelands. However, it should be supported by a good rainy season, to guarantee success (Petermann et al., 2008).

7.3 Livestock mediated reseeding

Livestock reseeding is another method suitable for implementation on degraded semi-arid communal rangelands (Gokbulak, 2006). It has the potential to restore rangelands and make them more productive (Savory and Butterfield, 2016; Aboling et al., 2008). Several advantages are associated with livestock reseeding; (i) Improved grass species diversity (ii) Re-introduction of good forage value species on rangelands (Figure 4.2) and (iii) Relevance of technology to semi-arid communal areas, [it is cheap and easy to implement, it does not require any form of expertise]. However, success of livestock reseeding is dependent on good timing as indicated by (Figure 4.1) which showed observed grass seedlings at Treatments 1 and 2 with a timeline of fourteen days after physiological seed maturity (Alabdulla, 2019; Dongre, 2007; Tessema et al., 2011). However, observed seedling densities gradually dropped as days progressed towards the end of the observation period (Figure 4.1). It is important to graze animals at the right time, to enable them to pick as many seeds as possible. After the stipulated grazing time the animals must be moved out and allowed to spent the next twenty-four hours in a degraded environment. Cow dung dropped during that period, will be containing mature seeds of different species grass (Shinde and Malshe, 2015; Gokbulak, 2006). The grass seeds will start to germinate in the subsequent growing season to fill the void caused by degradation.

7.4 Species diversity in livestock mediated reseeding

Observed species at Treatments showed diversity, (Figure 4.2) as indicated by species such as *Eragrostis superba*, *Eragrostis habrantha*, *Eragrostis rigidior*, *Urochloa panicoides* and *Dactyloctenium aegyptium* all of which had good forage value (Gibbs Russell et al., 1991; Cousens et al., 2010). All the species in (Table 4.2) and (Figure 4.4) save for *Dactyloctenium aegyptium* and *Urochloa panicoides* are perennials, which are common on sweet veld (Mugandani et al., 2012; Chippindall and Cook, 1976). However, although livestock are good agents for seed dispersion, it is interesting to note that *Heteropogon contortus* which is ubiquitous on most veld types was not among grass species dispersed by livestock. While it is not clear why *Heteropogon contortus*, was missing, it is probable that the grass species was shunned because its seeds are like little spears (Meyer et al., 1957). The little sharp spears cause injuries and irritations in the mouths of animals. Therefore, as a precaution, animals shunned it. In addition to the seeds of the Poaceae plant species dispersed by livestock, forbs were also observed; *Portulaca oleracea*, *Leucas martinicensis* and *Triumfetta rhomboidea* (Table 4.4). Forbs have high nutritive value of of approximately 30% CP (Mukungurutse, 2002) hence animals that take forbs during grazing, do not necessarily need browse (Sebata and Ndlovu, 2011). Results of the experiment prove clearly that livestock are good agents of seed dispersion (Gokbulak, 2006; Aboling et al., 2008). The methodology awaits adoption and validation in semi-arid communal areas where degradation is extensive. Development agents such as public and private extension services can conduct participatory restoration work with rural communities to rebuild rangelands so that they continue to support livestock production.

7.5 Fodder production in semi-arid communal areas

Serious degradation is a challenge, which impacts negatively on fodder availability thereby threatening the future of livestock production on semi-arid communal rangelands (Shackleton and Gambiza, 2008; Tarhouni et al., 2007). While restoration is an effective intervention for rebuilding degraded rangelands, the technology alone is not enough. It must be complemented by other interventions, such as fodder production adoption (CIAT and CGIAR, 2015; Kumar et al., 2022). Fodder production adoption in semi-arid communal areas can be the missing piece in a puzzle, which can solve feed shortages problem, which have been blighting livestock production over the years (Day et al., 2003; Prakashkumar and Sreenath, 2019). While fodder production adoption solves feed shortages, it has the potential to reduce grazing pressure on rangelands, which can enhance natural rangeland regeneration (Sasaki et al., 2012). Results of the fodder production adoption survey, (Figure 5.2), show 38.7% of the respondents were in the 51 to 60 years age group and those above 61 years 18.7%. Youths were few which is worrying because active fodder producers are elderly people, which casts doubt on the future of agriculture in the area. Results of the fodder production adoption survey show that 44% attained primary education, 50.7% secondary education, while 5.3% reached tertiary education. The literacy level of respondents was interestingly high (Figure 5.1).

Respondents were categorized into three classes according to the species of livestock they kept (Figure 5.4) showed respondents keeping goats constituted 50.7%, cattle; 46.7% and donkeys; 2,7%; Class 2; goats; 37.3%, donkeys; 28%, cattle; 6.7% and chickens; 28% while in Class 3, respondents who kept goats constituted a proportion of 10.7%, donkeys; 48%, cattle; 4%, pigs; 2.7% and chickens; 24%. All the livestock require dry season supplementation (Figure 5.5) 93.4% of the respondents, supplement livestock during the dry season. During this period, rangelands offer low quality and quantity feed and which affects animal performance seriously if mitigation measures are not taken. Respondents adopted fodder production as a long-term solution for safe guarding their livestock against poverty deaths (Musalila et al., 2016; Bhagawati and Paul, 2021; Bhandari et al., 2007). Supplemented livestock were categorized into three classes (Figure 5.5); Class 1; 45.3% of the respondents supplemented goats, cattle 49.3% and donkeys 4%. Class 2; 36% of the respondents supplemented goats, 29.3% donkeys, 6.7% and chickens 28%. In Class 3; 18.7% of respondents supplemented goats, donkeys 48%, cattle 1.3% and chickens 20%. Results show that respondents in Class 1 had larger proportions of cattle and goats while donkeys were low (4%). In Class 2, the trend is still the same but proportions were lower than those in Class 1, however, respondents who supplemented donkeys increased from 4% in Class 1 to 29.3% in Class 2. In Class 3, goats 18.7%, cattle 1.3% while donkeys accounted for 48%. The numbers of goats and cattle decreased from Class 1 to Class 3 while donkeys increased from Class 1 to Class 3. While the trend looks surprising, it is probable that donkeys in southwestern Zimbabwe are used as animal draft-power, hence the increasing proportions of donkeys that got supplementary feed.

(Figure 5.7) shows that 61.3% of the respondents used fodder to supplement livestock, 37.3% used both fodder and commercial feeds while 1.3% used commercial feed only. A proportion of 64% of respondents indicated supplementing livestock for a period of three to six months, 36% supplemented livestock for one to three months. Results of the fodder production adoption survey (Table 5.1) indicated 97.3% of the respondents noted reduced poverty deaths due to supplementing with fodder, although 2.7% of the respondents surprisingly indicated that poverty deaths increased. Proportions of respondents (Table 5.1) indicated that 40% of respondents produced an average of 250kg of fodder per year, 45.3% produced 251 to 500kg while 14.7% produced over 500kg. What comes out strongly is that respondents adopted fodder production as an adaptation strategy (Hargreaves et al., 2004; Thornton et al., 2010) since the areas are prone to droughts, which induce feed shortages (Day et al., 2003).

7.6 Other pull factors for the adoption of fodder production in semi-arid communal areas

Apparently, the objective of fodder production is dry season supplementation (Annicchiarico, 2004; Boller and Greene, 2010), however, results show that there are other factors which attract farmers to fodder production. Respondents noticed other benefits of growing fodder legumes (Figure 5.9). Six reasons were identified and responses were classified under three categories; Class 1, Class 2 and Class 3. One of the reasons for adopting fodder legumes was that species such as *Mucuna pruriens* controlled certain weed species (Ginwal et al., 2019). Responses in Class 1, 2.7% of the respondents said certain fodder legumes controlled some weed species, in Class 2, 9.3% also concurred while in Class 3, 38.7% also felt the same. (Figure 5.9) shows that 90.7% of the respondents indicated that *Striga asiatica* was controlled by a fodder legume, while

84% of the respondents indicated *Mucuna pruriens* controlled *Striga asiatica*. Two other reasons were prevention of soil erosion which had proportions of 33.3%, 37.3% and 25.3% in Casses 1, 2 and 3 respectively. Improvement of soil fertility had the following proportions of respondents 48%, 44% and 6.7% in Classes 1, 2 and 3 respectively (Shankar et al., 2022; Visha et al., 2023). This shows that while fodder legumes are important sources of crude protein during the dry season, there are other pull factors encouraging the adoption of fodder production in the semi-arid communal areas. It must also be remembered that the respondents practice a crop-livestock system of agriculture to enhance their food security. To this end, any measure that is beneficial to the agricultural activities is easily adopted.

7.7 The benefits of sustainable rangeland utilization

Semi-arid communal rangelands are important biomes whose obligation is to feed livestock (FAO, 2001). Farmers make great efforts to look after the environment, because they expect reciprocation from the environment. Needless to say, healthy land is more productive than degraded land. Sales of agricultural products bring incomes to families to satisfy their needs. However, the majority of respondents is composed of old people which is worrying (Figure 6.1). This casts doubt on the future of livestock production in the area. A proportion of 25% of the respondents were in the 41 to 50 years age group, 35% 51 to 60 years age group while those above 61 years constituted 22.5%. Gender proportions of respondents comprised 45% females and 55% males (Table 6.1), showing male dominance in agriculture despite the common narrative that the industry is dominated by females. However, it is also important to note that since some of the respondents were old, they could be pensioners. (Table 6.1) indicates that 10% of the respondents had never gone to school, 25% attended primary school, 50% attended secondary school while 15% attained tertiary education. The respondents were classified under two groups; those that have been farming in the area for less than ten years (27.5%) and those that have been farming in the area for above ten years (72.5%).

It was not clear why youths were not interested in agricultural activities. However, it is probable that since the area was closer to Botswana and South Africa, young people opted to cross into the neighboring countries to seek employment opportunities there (ZIMSTAT, 2018). However, what is surprising is that young people run away from partaking in agricultural activities in their home area, and go on to work in farms outside the country. It might correct to assume that because communal farmers are poorly resourced, most of their agricultural activities are carried out manually due to lack of machinery and this drives away young people from agriculture (Chambers and Conway, 1992) .

Since the respondents practice a crop-livestock system of agriculture, they also harvest grain from their fields. (Table 6.2) shows that 10% of the respondents get five to ten 50kg bags of grain, 10% eleven to fifteen 50kg bags, 30% sixteen to twenty 50kg bags and 50% get over twenty-one 50kg bags of grain in a good season. However, in a bad season 2.5% of the respondents got nothing, 27.5% get less than three 50kg bags of grain, 30% get less than five 50kg bags of grain while 40% get five to ten 50kg bags of grain. The result is enough proof to show that dry land cropping in semi-arid areas yields poor results (Murungweni et al., 2016), and on the other hand confirm that livestock production is a better agricultural option in the semi-arid areas (Musemwa et al., 2008). In (Figure 6.2), 75% of the respondents indicated that they produced grain for family consumption while 25% produced grain for sale. The grain is sold through three methods; 2.5% of respondents indicated contract farming, 45% sold to private buyers while 52.5% sold to the Grain Marketing Board (GMB), a quasi-government company.

Respondents who have been farming in the area for less than ten years (Table 6.5) kept livestock species in the following proportions of respondents; cattle 30.3%, goats 33.3%, sheep 3% donkeys 3%, pigs 3% and chickens 27.3%. Those that had been farming in the area for over ten years had the following proportions of respondents; cattle 31%, goats 31%, Sheep 10.3%, donkeys 3.4% and chickens 24.1%. Respondents in the second group had more cattle, sheep and donkeys than the ones in the first group. Both groups indicated that they sell livestock at one point or another (Table 6.6). Respondents who sold livestock showed that in the group of respondents who have been farming for less than ten years 33.3% sold goats, 30.3% sold cattle and 27.3% sold chickens. In the group of respondents who have been farming in the area for over ten years 31% sold cattle, 27.6% sold goats and 27.6% sold chickens. This group sold more cattle than the first one. The reason can be attributed to the fact that they are now more established farmers. Most of the livestock were sold to private buyers (Figure 6.3) showed that 95% of the respondents sold livestock to private buyers while 5% sold livestock to abattoirs. The results show that respondents don't have a good market for their livestock (Musemwa et al., 2008). By selling livestock to private buyers, the respondents are exposed to middlemen who usually want to pay very little for the livestock but get huge profits when they resell the animals.

The frequency of livestock sales (Figure 6.4), is indicated by 10% of the respondents who sell monthly, 52.5% who sell every three to six months, 2.5% sell livestock every six months while 35% sell livestock every six to twelve months. (Figure 6.5) shows that 12.5% of the respondents sell livestock when the family wants money, 5% sell livestock to buy food, 7.5% sell livestock to get money for school fees while 75% sell livestock for all the above reasons combined. This kind of behavior indicates that livestock is a store of wealth and can be sold in lieu of cash whenever it is needed in the family (FAO, 1992).

(Table 6.7) indicates the proportions of allocation of incomes from livestock sales to family needs. Respondents who have been farming in the area for less than ten years indicated that 33.3% allocated money to food, 33.3% to medication, 27.3% to school fees and 6.1% to restocking. In the group of respondents who have been farming for over ten years 19.8% allocated money to food, 32.6% to medication, 27.9% to school fees, 17.4% to restocking and 2.3% to savings. One interesting observation is that respondents in the over ten years group allocated less money to food but more on restocking and savings which respondents in the first group did not do. It is not clear why respondents who have been farming in the area for less than ten years do not allocate money for savings and less for restocking. What is clear is that livestock contribute greatly to livelihoods of semi-arid people (FAO, 1992). Considering that dry land farming is unreliable livestock give assurance to people's needs (Thornton et al, 2015).

Although respondents get money from livestock sales, they had other sources of income (Table 6.8). Respondents who had been farming in the area for less ten years show that 21.2% of them got money from remittances, 18.2% from crop sales, 6.1% from cattle sales, 9,1% from goat sales, 12.1% from piece jobs, 18.2% from monthly salaries and 15.2% from pension funds. Those in the group above ten years; 13.8% of the respondents received money from remittances, 23% from crop sales, 25.3% from cattle sales, 8% from goat sales, 8% from piece jobs, 6.9% from salaries and 14.9% from pension funds. The first group of respondents had larger proportions for remittances, monthly salaries, piece jobs and pension funds while the second group had larger proportions on crop sales and cattle sales. This can be attributed to the fact that they are more established than the second group, and as such they are depending to a large extend on their farming activities.

7.8 Recommendations

Due to the importance of semi-arid communal rangelands to livestock production, degradation on the rangelands, must be reversed to enhance productivity and resilience. Two possible interventions to rectify the anomaly are readily available (i) Reseeding and (ii) Livestock mediated reseeding. While results of this study indicate that the two methodologies can be used to rebuild semi-arid communal rangelands which have become derelict, extension services from both the public and the private sectors have the opportunity to validate the effectiveness of the two technologies. This could be undertaken in a participatory method that involves communities.

Although respondents in one of the surveys indicated that they adopted fodder production in order to enhance dry season supplementation, more work needs to be done so that many more farmers take up fodder production in semi-arid communal areas. The benefit of more numbers adopting fodder production, is that grazing pressure will be reduced from the rangelands. This will facilitate the recovery of the rangelands which are now seriously degraded.

Development agents should also consider introducing grazing management committees and plans to help better management of rangelands in semi-arid communal areas. While this approach can be difficult because land is communally owned, awareness campaigns and trainings can help to get buy-in of the idea from the farmers so that they support it. Traditional institutions such as Chiefs, Headmen and Village heads could be used as entry points to facilitate mobilization of communities to better manage natural resources in their areas.

Rather than waiting for the government to take the lead, communal farmers should be encouraged to sale older animals and use the money to restock. In this way livestock production in communal areas can remain sustainable.

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9 APPENDICES

APPENDIX 1: ANOVA for Chapter Three

```
"General Analysis of Variance."
BLOCK "No Blocking"
TREATMENTS Trt
COVARIATE "No Covariate"
ANOVA
[PRINT=aovtable,information,means,%cv,stratumvariance,cbmean; FACT=32;
CONTRASTS=7;\
 PCONTRASTS=7; FPROB=yes; PSE=diff,lsd,means; LSDLEVEL=5] t_ha
```

Analysis of variance

Variate: t_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Trt	3	0.51036	0.17012	9.50	<.001
Residual	91	1.62901	0.01790		
Total	94	2.13937			

Message: the following units have large residuals.

units 1	0.376	approx. s.e.	0.131
units 45	0.370	approx. s.e.	0.131
units 77	0.408	approx. s.e.	0.131

Tables of means

Variate: t_ha

Grand mean 0.215

Trt	CO1	SB	SR	SRB
	0.079	0.254	0.204	0.285
rep.	18	18	30	29

Standard errors of means

Table	Trt	
rep.	unequal	
d.f.	91	
e.s.e.	0.0315	min.rep
	0.0244	max.rep

Standard errors of differences of means

Table	Trt	
rep.	unequal	
d.f.	91	
s.e.d.	0.0446	min.rep
	0.0399	max-min
	0.0345X	max.rep

(No comparisons in categories where s.e.d. marked with an X)

Least significant differences of means (5% level)

Table	Trt	
rep.	unequal	
d.f.	91	
l.s.d.	0.0886	min.rep
	0.0792	max-min
	0.0686X	max.rep

(No comparisons in categories where l.s.d. marked with an X)

Combined estimates

No combined estimates (design orthogonal).

Estimated stratum variances

Variate: t_ha

variance	effective d.f.	variance component
0.0179	91.000	0.0179

Stratum standard errors and coefficients of variation

Variate: t_ha

d.f.	s.e.	cv%
91	0.1338	62.3

```
DELETE [REDEFINE=yes] _mean, _rep, _var, _resid, _rdf, _scode
AKEEP [FACTORIAL=9] Trt; MEAN=_mean; REP=_rep; VARIANCE=_var; RTERM=_resid; STATUS=_scode
IF _scode.IN.!(1,2)
  AKEEP [FACTORIAL=9] #_resid; DF=_rdf
  AMCOMPARISON [METHOD=fplsd; DIRECTION=descending; PROB=0.05] Trt
```

Fisher's protected least significant difference test

Trt

	Mean	
SRB	0.2853	a
SB	0.2545	ab
SR	0.2040	b
CO1	0.0785	c

```
ELSE
  PRINT !t('Multiple comparisons available only if all components of the term',\
'are estimated with equal efficiency and in the same stratum.');\
JUST=left
ENDIF
```

APPENDIX 2: Questionnaire for Chapter five

MATOPOS RESEARCH INSTITUTE

An assessment of adoption and utilization of forages as dry season supplement in the smallholder sector of semi-arid regions

QUESTIONNAIRE

Guiding Instructions for the Enumerator
1. Briefly introduce yourself 2. Explain the purpose of the interview
This questionnaire serves as a tool for obtaining information on adoption and use of forages as dry season supplementary feed in semi-arid areas to mitigate feed shortages. Answers from respondents will be treated confidentially. All information given will be used for purposes of producing scientific reports.

PARTICIPANT'S LOCATION	
Name of Observer:	Date:
Ward:	GPS coordinates:
Village:	
Line:	

SECTION A Demographic Information

When answering questions write the number with the appropriate answer in the box

A1 Gender of household head 1 = Male 2 = Female

A2 Age of respondent

(a) 16 - 25	1
(b) 26 - 30	2

(c) 31 - 35	3
(d) 36 - 40	4
(e) 41 - 50	5
(f) 51 - 60	6
(g) 61 and above	7

A3 Age of the household head

(a) 16 - 25	1
(b) 26 - 30	2
(c) 31 - 35	3
(d) 36 - 40	4
(e) 41 - 50	5
(f) 51 - 60	6
(g) 61 and above	7

A4 Highest level of education of respondent

(a) Never went to school	1
(b) Primary school	2
(c) Secondary school	3
(g) Tertiary	4

A5 How long have you been farming in this area?

(a) < 10 years	1
(b) > 10 years	2

A6 How many dependents do you have?

Write number of people	

SECTION B FORAGE PRODUCTION, CONSERVATION AND UTILIZATION

B1 What type of farming system do you practice at your household?

(a) Crop - livestock	1
(b) Crops only	2
(g) Livestock only	3

B2 Choose the 3 livestock species in their order of importance that you keep

(a) Goats	1
(b) Donkeys	2
(c) Cattle	3
(d) Sheep	4
(e) Pigs	5
(f) Chickens	6

B3 During which time of the year do you experience feed shortages?

(a) Summer	1
(b) Dry season	2

B4 Choose 3 livestock species in their order of importance that you supplement

(a) Goats	1
(b) Donkeys	2
(c) Cattle	3
(d) Sheep	4
(e) Pigs	5
(f) Chickens	6

B5 For how long do you supplement your livestock per annum?

(a) <1 month	1
(b) 1 - 3 months	2
(c) 3 - 6 months	3
(d) All year round	4

B6 What feedstuffs do you use for supplementation?

(a) Commercial feed	1
(b) Forages	2
(d) Both	3

B7 Which feed stuffs are easily available to you?

(a) Commercial feed	1
(b) Forages	2
(d) Both	3

B8 Choose 3 forage crops you grow in their order of importance

(a) Cowpeas	1
(b) Bana grass	2
(c) Mucuna	3
(d) Forage sorghum	4
(e) Lablab	5
(f) Sunnhemp	6

B9 How do you conserve the forages?

(a) Hay (*Dry form*)	1
(b) Silage (*Fresh form*)	2

B10 In what way has forage supplementation benefitted your livestock?

(a) Poverty deaths dropped	1
(b) Numbers have increased	2

B11 How much forage material do you harvest per year?

(a) < 250kg	1
(b) 251 – 500kg	2
(c) > 500kg	3

B12 Before you started supplementing your livestock with forages how was the mortality rate of kids, lambs, calves and foals?

(a) It was high	1
(b) It was low	2
(c) There was no change	3

B13 How has supplementing your livestock with forages improved the milking period?

(a) It increased	1
(b) It decreased	2
(c) There was no change	3

B14 How many people in your area did you advise to grow forages for their livestock?

(a) < 5	1
(b) 6 - 10	2
(c) 11 - 15	3

B15 What is your comment about the number of people growing forages in your area?

(a) It is increasing	1
(b) It has not changed	2
(c) It is decreasing	3

SECTION C OTHER BENEFITS OF FORAGES

C1 Choose 3 other benefits of forages in order of their importance

(a) Improve soil fertility	1
(b) Protect soil erosion	2
(c) Kill some weed types	3
(d) Cover crop	4
(e) Reduce evapo-transpiration	5
(f) Improve infiltration	6

C2 Which forage legume kills some species of weeds?

(a) Lablab	1
(b) Mucuna	2
(c) Cowpeas	3

C3 From your own observation which weed has been wiped away by Mucuna?

(a) Upright starvur	1
(b) Witch weed	2
(c) Rapoko grass	3

C4 Would it be correct to say that some forage legume species can be used for the biological control of certain species of weeds?

(a) I disagree	1

(b) I agree	2
(c) I strongly agree	3

C5 How people have you told about using some legume forage species to control certain types of weeds?

(a) < 5 people	1
(b) 6 – 10 people	2
(c) 11 – 15 people	3

C6 What is your comment about the yield of a cereal crop following a forage legume crop?

(a) It Increases	1
(b) It goes down	2
(c) There was no change	3

THANK YOU FOR PARTICIPATING

APPENDIX 3 Questionnaire for Chapter Six

MATOPOS RESEARCH INSTITUTE

An analysis of the economic contribution of livestock to food security and livelihoods and the allocation of incomes from livestock sales to family needs in the smallholder sector of the semi-arid regions

QUESTIONNAIRE

Guiding Instructions for the Enumerator
1. Briefly introduce yourself. 2. Explain the purpose of the interview
This questionnaire serves as a tool for gathering information on how incomes from livestock sales are allocated to family needs of people living in the smallholder sector of the semi-arid regions. Answers from respondents will be treated confidentially. All information given will be used for purposes of producing scientific reports.

PARTICIPANT'S LOCATION	
Name of Observer:	Date:
Ward:	GPS coordinates:
Village:	
Line:	

SECTION A Demographic Information

When answering questions write the number with the appropriate answer in the box

A1 Gender of household head 1 = Male 2 = Female [ ]

A2 Age of respondent

(a) 16 - 25	1

(b) 26 - 30	2
(c) 31 - 35	3
(d) 36 - 40	4
(e) 41 - 50	5
(f) 51 - 60	6
(g) 61 and above	7

A3 Highest level of education of respondent

(a) Never went to school	1
(b) Primary school	2
(c) Secondary school	3
(g) Tertiary	4

A4 How long have you been farming in this area?

(a) < 10 years	1
(b) > 10 years	2

A6 How many dependents do you have?

Write number of people	

SECTION B SOCIO-ECONOMIC INFORMATION

B1 Choose 3 major sources of the household income in their order of importance

(a) Remittances	1
(b) Crop sales	2
(c) Cattle sales	3
(d) Goat sales	4
(e) Piece-jobs	5
(F) Monthly salary	6
(g) Pension	7

B2 Choose 3 crops grown by the household in their order of importance

(a) Maize	1
(b) Sorghum	2
(c) Pearl millet	3
(d) Ground nuts	4
(e) Cowpeas	5
(f) Bambara nuts	6

B3 What is the household's annual harvest during a good year?

(a) 5 – 10 (50kg bags)	1
(b) 11 – 15 (50kg bags)	2
(c) 16 – 20 (50kg bags)	3
(d) 21 and above	4

B4 What is the household's annual harvest during a bad year?

(a) 5 – 10 (50kg bags)	1
(b) < 5 (50kg bags)	2
(c) < 3 (50kg bags)	3
(d) 0 (50kg bags)	4

B5 What do you produce your grain for?

(a) Family consumption	1
(b) Sale	2

B6 Where do you sell your grain?

(a) GMB	1
(b) Private buyers	2
(c) Contract farming	3

B7 Choose in order of importance 3 livestock species kept at the household

(a) Cattle	1
(b) Goats	2

(c) Sheep	3
(d) Donkeys	4
(e) Pigs	5
(f) Chickens	6

B8 Choose in order of importance 3 livestock species you sell most

(a) Cattle	1
(b) Goats	2
(c) Sheep	3
(d) Donkeys	4
(e) Pigs	5
(f) Chickens	6

B9 How often do you sell the chosen livestock species per year?

(a) Every month	1
(b) 3 – 6 months	2
(c) 6 - 12 months	3

B10 Where do you sell your livestock?

(a) Private buyers	1
(b) Auctions	2
(c) Abattoirs	3

B11 When do you sell your livestock?

(a) When family needs money	1
(b) When family wants to buy food	2

(c) When school fees are needed	3
(d) All the above	4

B12 Choose 3 items in order of importance you use the money for after selling livestock

(a) Buying food	1
(b) Buying medicine	2
(c) Paying school fees	3
(d) Keeping the money	4
(e) Buying beer	5
(f) Buying other livestock	6

B13 Is the choice in Question B12 above a good one?

(a) I agree	1
(b) I strongly agree	2
(c) I disagree	3

THANK YOU FOR PARTICIPATING