CLIMATE VARIABILITY AND ADAPTATION IN AGRO-PASTORAL PRODUCTION SYSTEMS OF SOUTHERN ZAMBIA

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A PHD THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN DRYLAND RESOURCE MANAGEMENT, DEPARTMENT OF LAND RESOURCE MANAGEMENT AND AGRICULTURAL TECHNOLOGY, UNIVERSITY OF NAIROBI, KENYA

DATE: MAY 2013

DECLARATION AND APPROVAL

I hereby declare that this Thesis is my own original work and has not been presented for an award of a degree in any other university.

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DEDICATION

This Thesis is dedicated to:

Firstly my beloved wife Carolyn Esinara Banda for her unmatched strength and support during my absence from home for course work, daughter Joanna Chabota Chimwemwe who was born the day I was taking the last examination, daughter Jessica, son Joel and son Jedidiah for your patience and understanding. To you all, may the Almighty God make you to also rise to greater heights in life.

ACKNOWLEDGEMENTS

I express my sincere and special thanks to Dr. Moses M. Nyangito of University of Nairobi, Dr. Joseph Simbaya of University of Zambia, Prof. Nashon K. R. Musimba of South Eastern University College for their valuable guidance and supervision throughout the research work and publication of the work. Thanks also go to the Head of Animal Science Department, University of Zambia, Dr Drinah Banda Nyirenda for her support and encouragement during field work, Dr Moses Daura of the University of Zambia for his valuable advice during research.

Special thanks also go to Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for financial support for this work and the many opportunities to improve on the work through scientific workshops and conferences and Prof Kinuthia Ngungi for coordinating the RUFORUM scholarship programme, University of Nairobi.

I am highly indebted to the research assistants who helped with the questionnaire survey and Mr Chooka Muyangali for helping organise the Focus Group Discussions. To the Tonga agropastoralists for their time and cooperation and for allowing us to carry out the research. The laboratory technicians at the University of Zambia Department of Animal Sciences, especially Ms Ann Maliti.

To my wife, sons and daughters and relatives for being there when I needed you and to the Almighty Lord and Saviour Jesus Christ without whom we can do nothing

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LIST OF ABBREVIATIONS/ACRONYMS

AAAS	:	American Association for the Advancement of Science
ADF	:	Acid Detergent Fibre
AFORNET	:	African Forest Research Network
AOAC	:	Association of Official Analytical Chemists
CEEPA	:	Centre for Environmental Economics and Policy in Africa
CP	:	Crude Protein
CSO	:	Central Statistics Office
DFID	:	Department for International Development
DM	:	Dry Matter
FAO	:	Food and Agricultural Organisation of the United Nations
FASAZ	:	Farming Systems Association of Zambia
GDP	:	Gross Domestic Product
ICRAF	:	International Centre for Research in Agroforestry.
ILRI	:	International Livestock Research Institute
IPCC	:	Intergovernmental Panel on Climate Change
IRIN	:	Integrated Regional Information Networks
IRRI	:	International Rice Research Institute
IVDMD	:	*In-vitro* Dry Matter Digestibility
LEAD	:	Livestock Environment and Development
METNR	:	Ministry of Environment Tourism and Natural Resources

NDF	:	Neutral Detergent Fibre
NGO	:	Non-Governmental Organisation
RUFORUM	:	Regional Universities Forum for Capacity Building In Agriculture
SSA	:	Sub-Saharan Africa
TLU	:	Tropical Livestock Unit
UN	:	United Nations
UNEP	:	United Nations Environmental Programme
USAID	:	United States Agency for International Development
WFS	:	World Food Summit

ABSTRACT

Climate variability and change which manifests itself through increase in temperature and frequent occurrence of floods and droughts is increasing agro-pastoralists vulnerability and inability to sustain their sources of livelihood, hence their need for coping adaptive strategies. This study was undertaken in the drylands of Choma District in Southern Zambia to generate information to aid in coming up with sustainable coping strategies as an adaptation to climate variability. The objectives of the study were to: Determine the extent of climate variability and the agro-pastoralists coping strategies in extreme weather conditions; Identify the livestock feeding strategies employed by agro-pastoralists as an adaptation in extreme weather conditions; Evaluate preferred local fodder tree/browse productivity for high dry season biomass yield by coppicing at different levels; and Determine the nutritive quality of the preferred browse species using *in-vitro* digestion in order to ascertain the most appropriate stage of feeding to animals. Semi-structured interviews and focused group discussions were used to capture primary data. Secondary data was also collected. Effects of coppicing on the preferred drought tolerant browse tree was conducted. The treatments were percent removal of the stems at 25, 50 and 75% replicated three times. After one year, measurements on the number of shoot re-growth and biomass yield were done. A survey was also conducted to determine intensity of harvesting of the preferred browse tree by the agro-pastoralists. *In-vitro* dry matter digestibility trials of leaves of the preferred browse tree at four different post-sprouting stages were conducted to determine their nutritional quality as dry season feed for ruminants. Data sets were subjected to descriptive trend analysis, and analysis of variance as appropriate. The study revealed that there has been an increase of 1.0 ^{o}C in the average annual temperatures over the previous five decades. Variability in the amount of annual rainfall received has increased by 33% over the same period while there was a general decline in average annual rainfall received. Most of the agro-pastoralists are coping with these extreme weather conditions through sale of livestock and harvest of forest products, which can pose a threat to sustainable use of the forest resources in the long run. The major livestock feeding strategies during extreme weather conditions were upland grazing and browse utilization and 17 browse species were identified by the agro-pastoralists as being important. Coppicing of the highly preferred browse *Julbernardia globiflora* showed that browse trees subjected to higher coppicing intensity had significantly less number of new shoots and dry matter yield ($P<0.05$). Leaves from the early stage of leaf sprouting gave the best nutritive quality with significantly higher crude protein and *in-vitro* digestibility levels compared to the other sprouting stages ($P<0.05$). There is need to enhance some of these adaptive strategies to ensure survival in view of anticipated increase in frequency, intensity and magnitude of extreme weather conditions. Harvesting of forest products should be done sustainably to reduce pressure on the forest and avoid de-forestation. Deliberate effort should be made to capacity build the agro-pastoralists on how to plant and manage browse species such as *Julbernardia globiflora* that are adaptable in extreme weather conditions for productive use of the browse species for improved animal feeding and enhanced food security. Also agro-pastoralists should be able to take up management and feed conservation measures for their animals.

THESIS ORGANISATION

The Thesis is organised into Introductory Chapters and paper format Chapters, where Chapters 1,2and 3 are the Introductory Chapters while Chapters 4,5,6and 7 are paper format Chapters. Chapter 1 deals with General introduction, Chapter 2 comprises of literature review and Chapter 3 deals with materials and methods. The paper format Chapters are based on specific issues of the study derived from the specific objectives. Chapter 8 deals with the general discussion, which ties up the various key issues across the Thesis culminating in recommendations and areas for further research.

CHAPTER ONE
GENERAL INTRODUCTION

1.1 Background Information

Dry lands cover about 40% of the world's surface, provide an important source of livelihood to local communities and are home to 2 billion people (FAO2009). These include the poorest and the least developed nations on earth whose main source of livelihood is pastoralism and agro-pastoralism. In Sub-Saharan Africa, 40% of the land is dedicated to pastoralism IRIN (2004) and provides source of livelihood for 25 million pastoralists (people whose livelihood is based on mobile livestock keeping) and over 200 million agro-pastoralists (people combining mobile livestock keeping with agriculture) (SNV Practice Brief 2012). They represent over a quarter of the total population in Africa. However, desertification and land degradation are reducing the capacity of the land to sustain livelihoods. Agriculture accounts for around 30 per cent of the region's GDP, 20 per cent of merchandise exports, and 60 per cent of employment. Agriculture-based development is not only fundamental to cutting hunger and reducing poverty but also to generating economic growth, reducing the burden of food imports and opening the way to a moderate expansion of exports(Otte and Knips 2005). Livestock production currently contributes about 35 per cent of agricultural GDP(and if non-food products and services were added this share would even be higher) (Cranefield*et al*.2002). The livestock sector contributes between 20 to 50 percent to agricultural valued added products in African countries with a continental average of 26 percent and is expected to become the largest contributor to agriculture as economic development progresses. This is due to the growing demand for high-value food items, including meat and dairy products (FAOSTAT2011).In Zambia the trend is similar where agriculture contributes 21 % of the GDP. The livestock sub-sector, though relatively unexploited is recognized as an increasingly dynamic part of the agricultural industry. The sub-sector contributes about 35 percent to Agriculture Gross Domestic Product and has the potential to expand its contribution to national economic growth, given Zambia's abundant natural resource base(Ministry of Agriculture and Livestock 2012).

Despite the high economic and environmental potential of drylands, and the significant contribution of its agriculture to the GDP, most statistics show high levels of poverty in agro-pastoral areas. The arid and semi-arid districts of Kenya, Uganda, Zambia, Ethiopia as well as North-Ghana and Benin are among the poorest in these countries(SNV Practice Brief 2012). This is because current poverty reduction efforts are not reaching the poorest and most marginalised groups within underdeveloped countries, of which pastoral categories form a large part. Poverty is higher in most African countries than elsewhere in the developing world. In Sub-Saharan Africa (SSA), 50 per cent of the total population or 300 million people live on less than 1$ per day and is especially prevalent in rural areas where an estimated 70 per cent or 210 million of the poor people live(Otte and Knips 2005). The prevalence of widespread chronic poverty and human disease is linked to the weak economic performance of SSA countries. Most of these rural poor depend on pastoralism and agro-pastoralism as a source of livelihood. In Zambia rural poverty rates have also remained very high, i.e 80%, over the past decade and a half, whilst urban poverty rates have declined, from 49% in 1991 to 34% in 2006 (Chapoto *et al.*2011). Sub-Saharan Africa with 11 per cent of the global population has an estimated 73percentof global HIV/AIDS related infections (World Bank 2011). So far over 20 million Africans have died of HIV/AIDS, 14.5 million children have been orphaned and many families have lost their labour supply as adults have fallen ill or died (World Bank 2011).

1.2 Problem Description and Justification

The concentration of poor people in rural areas and their predominant involvement in agriculture means that SSA rural well-being is closely linked to agricultural performance. Improving agro-pastoralists' livelihoods is closely linked to meeting some of the challenges confronting drylands today, including: loss of biodiversity through conversion of grazing land to modern agriculture and industries and human population growth and pressure of scarce resources; the challenge of the HIV/AIDS pandemic and climate variability and change which leads to food insecurity. Recurrent droughts and floods are a serious threat to the sustainability of agro-pastoral production system, and the people relying on these systems are increasingly facing food shortages.

Enhancing agricultural and livestock production in particular and in view of climate variability and change, is important for long term economic wellbeing of the agro-pastoralists. Pica *et al.*(2008) found a statistically significant causal relationship between livestock sector development and economic growth in 18 of the 20 African countries analyzed, strongly suggesting that increases in value-added per Tropical Livestock Unit (TLU) are a driver of GDP per capita growth. In general, increased agricultural productivity, including livestock, is anticipated to lower food prices, which directly benefits the poor and generates a surplus of products and by-products that can be exported from agriculture to the rest of the economy, thereby facilitating economic growth and poverty reduction (Tiffin and Irtz 2006). Livestock in the household economy are one of the most common and important assets among rural households in Africa. The continental data produced by International Livestock Research Institute (ILRI) in 2002 through overlaying population and poverty data on livestock production systems, indicate that over 53 percent of the population keeps some livestock in sub-Saharan Africa, i.e.,that one out of two persons in the continent are partly dependent on livestock for their livelihoods (ILRI 2002). Furthermore SSA has the largest area of permanent pasture of any continent, and the largest number of pastoralists (Ogle 1996).

Livestock production can contribute to poverty reduction in various ways. It can increase food supply, serve as a source of income and a means for capital accumulation, generate employment and supply inputs and services for crop production. Yet there is under and/or improper utilization of available indigenous natural resources in agro- pastoral areas due to inadequate scientific attention and information. The situation has been made worse due to the fact that agro-pastoralists are often ignored in developmental debates and efforts that focus on food security are only in terms of crop production (Parry *et al.*1999, FAO 2006, IPCC 2007). The majority of the rural poor have been excluded from the policies and development decisions that affect crop and livestock production systems and which, to a great extent, have marginalized and excluded these communities from influencing the process of change. Yet, poor communities are held responsible for and share the consequences of the poor management, low productivity and continued deterioration of renewable resources(Sidahmed and Kessaba 1997).To add on to this, researchers and development experts have previously deliberately overlooked the indigenous knowledge in the development of research agendas for the agro-pastoral dryland areas. Abate *et al.* (2009) indicated that development interventions that did not integrate traditional range management strategies have not been successful. A combination of pastoral indigenous knowledge and modern scientific information may be helpful in providing a better understanding of the environment from the perspective of those utilizing the resources (Ayana and Gufu 2009).

The ability of the agro-pastoralists to survive for the past many years in their productive system shows that they have been involved in some level of adaptation and they have been using various coping strategies for their survival. However, with the increase in the frequency of extreme weather conditions, the landscape has changed over the years and is likely to continue changing in the future. With the United Nations (UN) predicting of 3-4 degrees Celsius increase in temperature by 2080, Africa will be hard hit by global warming (United Nations2008). The farmers efforts to subsist on the land are going to be challenged and their resilience will be gradually eroded (Mogotsi *et al.*20ll).There is therefore need to identify and enhance coping strategies that will enable them to live and adapt to these serious environmental changes.

Whereas a lot of work has been done in deriving various strategies to improve the availability of fodder, lack of strategies that address the effect of climate variability and change on animal feed resources has led to no improvement in feeding of pastoral animals. There is therefore need to focus on the understanding of available indigenous forage species and the way these resources are utilised by the agro-pastoralists in mitigating the effects of climate variability. Documentation and use of the indigenous knowledge will help to avoid potential loss of this knowledge and contribute to making better use of locally available natural resources. This will also ensure that the identified important indigenous natural resources will be preserved for long term use, hence reducing biodiversity loss due to agricultural modernization.

1.3 Research Objectives and Questions

The overall aim of the study was to contribute to generation of knowledge to aid in the development of coherent management strategies on livelihoods in view of climate variability and change. The specific objectives of the study were:

(1) To determine the extent of climate variability and change, and the agro-pastoralists coping strategies in extreme weather conditions.

(2). To document the livestock feeding strategies employed by agro- pastoralists and identify the important browse species used in extreme weather conditions in order to improve their utilization for improved livestock production,

(3). To evaluate the most preferred browse tree productivity for high dry season biomass yield by coppicing the browse at different levels so as to identify appropriate browse harvesting regimes and

(4). To determine the nutritive quality of coppiced browse re-growth in line with appropriate stage of feeding to animals.

The four specific objectives are reflected in the following research questions.

1. What is the extent of climate variability and change and the agro-pastoralists coping strategies in extreme weather conditions in the study area?
2. What are the feeding strategies employed by agro- pastoralists and the important browse species used in extreme weather conditions in order to improve their utilization for improved livestock production?
3. What is the dry season biomass yield of coppiced browse trees at different levels and appropriate browse harvesting regimes?

4. What is the nutritive value of coppiced re-growth at different stages and appropriate stage of feeding to animals.

CHAPTER TWO
LITERATURE REVIEW

2.1 Climate Change and Climate Variability

Climate change is the change in the statistical properties of the climate system when considered over long periods of time regardless of the cause (IPCC 2001) while climate variability refers to variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events (USAID 2007). Climate variation manifests itself in extended drought, floods and conditions that result from periods of El Nino and La Nino events. These fluctuations take place over periods that are shorter than a few decades. The relationship between climate and food security is obviously not a new issue. In Rome in 1974, for example, the United Nations convened a now famous World Food Conference under the guidance of the UN FAO. It reminded governments of an urgent need to focus on existing and yet-to emerge food security and related issues. Thirteen years later (1987), the International Rice Research Institute (IRRI) and the American Association for the Advancement of Science (AAAS) convened an international symposium to address concerns about climate, weather and water impacts on agricultural production. The very same issues of concern to policy-makers today were addressed by scientific researchers then. In the 1970s no attention was paid to mitigation and concerns about adaptation to climate were centred on weather extremes and climate variability from season to season and year to year to address the crucial aspect of food production stability, one of the pillars of food security. By 1996, however, the World Food Summit (WFS) recognized that the resource base for food, agriculture, fisheries and forestry was under stress and threatened by problems such as desertification, deforestation, over fishing, loss of biodiversity, inefficient use of water, and climate change. Mainly under its commitment three, the WFS made a number of explicit references to the dominant role of climate fluctuations in food supply as one of the main factors interfering with sustainable increases in food production. Today's concern about climate change has added features to the issue of food security. Figure 2.1.1, shows the food production system and how it is affected by weather parameters such as drought.

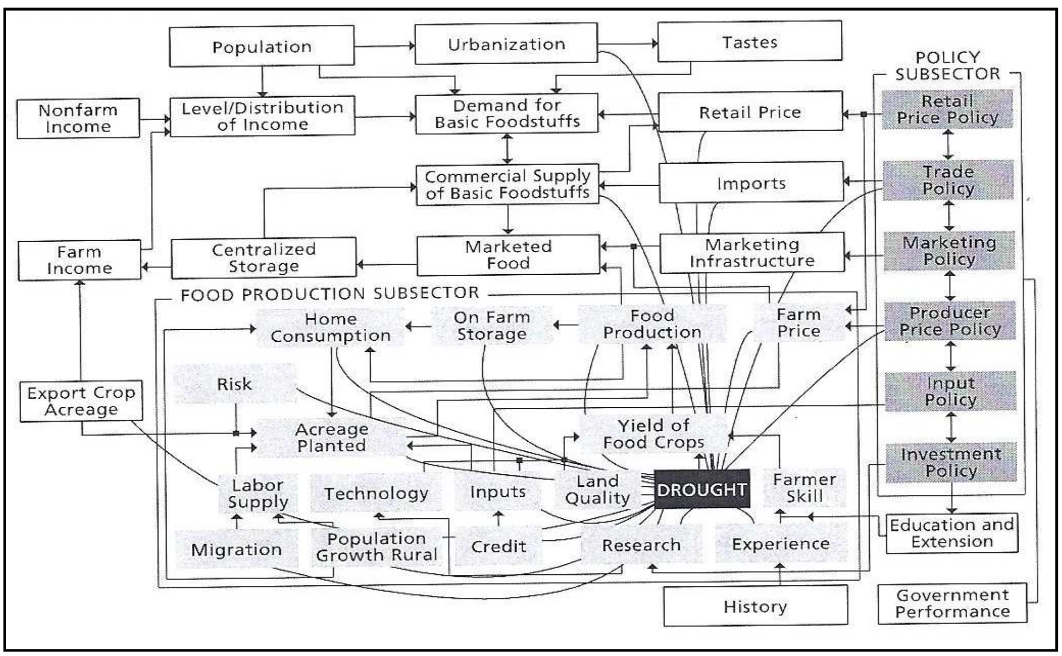


Figure 2.1.1 Schematic diagram showing food production system in which drought is one of the affecting parameter. Source FAO 2009

Climate change is already affecting all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. The impacts are both short-term, through more extreme weather events, and long term through changing temperatures and precipitation patterns. Rural communities and livelihoods face immediate risk of increased crop failure, loss of livestock, and reduced availability of marine, aquaculture and forest products and new patterns of pests and diseases outbreak. People living in fragile ecosystems such as coasts, floodplains, mountain areas and semi-arid landscapes are most at risk (FAO 2009). Climate change can cause biodiversity loss, drought and desertification and can lead to unsustainable land utilization. The result will be loss of agricultural productivity, reduced capacity to sustain rural livelihoods and increases risk of, and vulnerability to natural and human disasters. Figure 2.1.2, shows that climate variability negatively affects all types of capital resources which are important to agro-pastoralists for their survival. These include human capital, natural capital, social capital, financial capital and physical capital. Human capital can be affected by having people with poor nutrition and health as a result of climate variability. People with poor education levels and skills will not be able to adapt to changes demanded by new weather patterns. Social capital will deteriorate with increased climate variability and will manifests itself in local, regional and even international disputes, conflicts and wars over the reduced natural resources.

Refocusing efforts and investment on proper utilization and management of these capital resources is a prerequisite to secure the lives and livelihoods of millions of people worldwide and to sustain the range of products and services provided by the environment in the short and long term of the rural poor people living on less than one dollar a day.

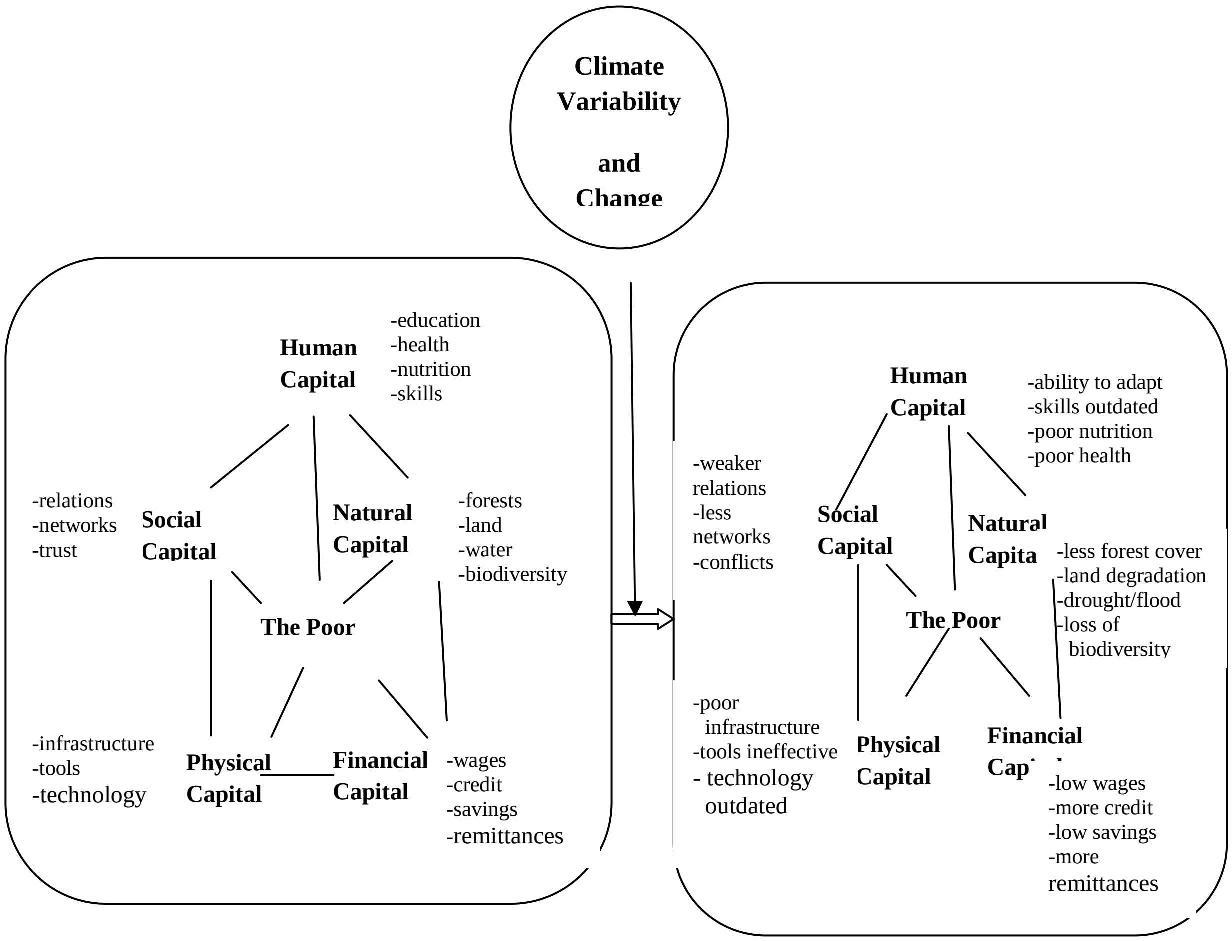


Figure 2.1.2 Sustainable livelihood framework showing interaction between livelihood resources and climate change and variability. Adapted from IFAD 2001

2.2 Livelihood Coping Strategies and Adaptation

Coping strategies are defined as specific efforts, both behavioural and psychological, that people employ to master, tolerate, reduce or minimize stressful events (John and

MacArthur 1998). Adaptation refers to the adjustment in natural or human system in response to actual or expected climate stimuli or their efforts which moderate harm or exploits beneficial opportunities (IPCC 2007). These adjustments are intended to reduce the vulnerability of society to changes in the climate system (Kates 2000). Adaptive capacity is the capacity to cope with impacts of climate variability and change (Smit and Pilifosova 2002). Moreover adaptation to changes including climate variability is a dynamic process and should as a survival mechanism display enough flexibility to accommodate new components (UNEP - ICRAF 2006). Adaptation to changing conditions is the most immediate concern for sectors of agricultural production and that vulnerability to impacts varies greatly from population to population and can even vary in the same location from time to time. Adaptation concerns are based on the identification of likely impacts of global warming at national, local and household levels and they are increasingly focusing on the development of both proactive and reactive coping mechanisms to soften, if not avoid, those impacts.

New coping strategies must ensure that the use of resources is re-looked, re-oriented and re-organised to be able to meet the new challenges associated with climate variability. Livelihood strategies which lead to the destruction of the natural resources should be discouraged while more sustainable means should be identified and supported by all stakeholders in order to create a stable global environment. Adaptation and mitigation strategies should contribute to poverty reduction and at the same time must benefit the most vulnerable communities without harming the environment. Informing about climate change impacts, vulnerability patterns, coping and adaptive capacity as well as facilitating location specific adaptation and mitigation practices are of central concern. The uncertainties related to climate change impacts and vulnerabilities are often considered as an impediment for concrete and immediate action. However, uncertainty is a fundamental component of climate impacts and cannot, in itself, be used as an excuse for inaction. There is need for better informed decisions on "resilient adaptation" by merging adaptation, mitigation and prevention strategies. It is important for policy-makers, institutions, societies and individuals to find improved ways of identifying most at-risk communities and "best practices" of coping with current climate variability and extreme climate events. Table 2.2.1 provides few illustrative examples of planned adaptation options, underlying policy frameworks, constraints and opportunities in the water and agriculture sector (IPCC 2007b). They have a direct relevance to food security.

Table 2.2.1 Selected examples of planned adaptation in water and agriculture sector

Adaptation Option/Strategy	**Underlying Policy Framework**	**Constraints**	**Opportunities**
Expansion of rainwater harvesting; water storage and Conservation techniques; water reuse; desalination; water-use and irrigation efficiency	National water policies and integrated water resources management; water-related hazards management	Financial, human resources and physical barriers	Integrated water resources management; synergies with other sectors
Adjustment of planting dates and crop variety; crop relocation; improved land management, e.g. erosion control and soil protection through tree planting	R&D policies; institutional reform; land tenure and land reform; training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits	Technological and financial constraints	Access to new varieties; markets; longer growing season in higher latitudes; revenues from 'new' products

Source: IPCC 2007

Climate mitigation is any action taken to permanently eliminate or reduce the long-term risk and hazards of climate change to human life and property. The International Panel on Climate Change (IPCC) defines mitigation as: "An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases." Although several social, economic and technological policies would also lead to emissions reduction, for climate change, mitigation encompasses implementing policies to reduce greenhouse gas emissions and to enhance sinks. Table 2.2.2 provides selected examples of mitigation technologies, policies and measures as well as constraints and opportunities for agriculture and forests as outlined in the IPCC (2007) report.

In Zambia the Agro-pastoralists have not been spared from theses extreme weather conditions. METNR 2007, reported that in Zambia the increase in frequency, intensity and magnitude of climate variability over the past two decades have adversely impacted on food security, water security, water quality, energy and sustainable livelihoods for the rural communities. Using the Zambian case it is important to examine the magnitude climate variability the agro-pastoralists' perception of climate variability and the coping and adaptive strategies that they employ when faced with this vice. There is also need to look at the possibility of increased diversification of livelihood strategies.

Table 2.2.2. Key mitigation technologies and practices in agriculture and forestry, policies and measures, constraints and opportunities.

Key Mitigation Technologies and Practices	**Policies, Measures and Instruments Shown to be Environmentally Effective**	**Key Constraints**	**Key Opportunities**
Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation; techniques and livestock and manure management to reduce CH4 emissions; improved nitrogen fertilizer application techniques to reduce N2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency; improvements of crop yields.	Financial incentives and regulations for improved land management; maintaining soil carbon content; efficient use of fertilizers and irrigation		May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation
Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bio-energy to replace fossil fuel use; tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change; Landfill management and monitoring	Financial Incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests; land use regulation and enforcement	Constraints include lack of investment capital and land tenure issues	Can foster poverty alleviation

Source: IPCC 2007

The DFID sustainable livelihood framework (Figure 2.2.1) looks at people's existing assets, builds on strengths and seeks to understand their own needs and priorities and then addresses the complex issues and relationships that affect their livelihoods. It presents shocks, trend and seasonality (for example drought) as conditions that lie furthest from people's control. The fragility of the poor means that they are least able to cope with the negative impacts of these conditions. Livelihood assets are the resources people employ as part of their livelihood strategies in order to achieve their livelihood outcomes. Increased assets can empower people and influence the policies, institutions and processes that affect their livelihoods. Institutions may discriminate against the poor and inhibit their access to livelihood assets. Women, children and ethnic minorities are the most likely to suffer as a result of institutional discrimination. Livelihood outcomes are 'outputs' of strategies as they try to meet the challenge from the existing source of vulnerability. Positive outcome are likely to include more income, increased well being, reduced vulnerability, improved food security and more sustainable use of resources.

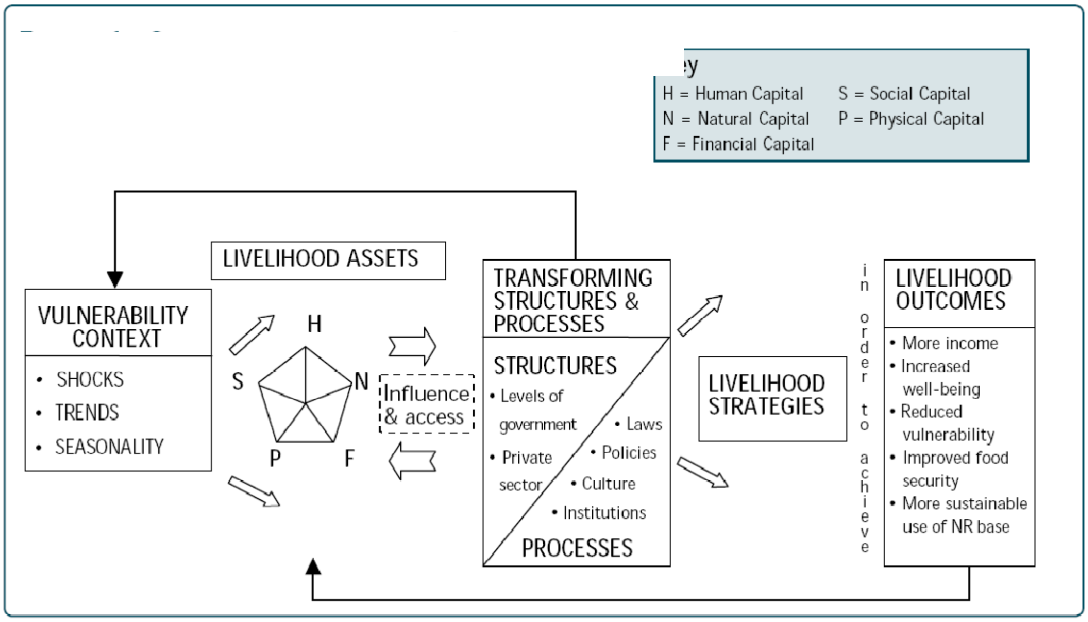


Figure 2.2.1 The DFID sustainable livelihood framework. Source: DFID 1999.

2.3 Land Tenure and Climate Change

Although the linkages between climate change and land tenure are complex and indirect, the effects of climate change and variability are felt through changes in natural ecosystems, land capability and land use systems. Increasingly, these changes will place diminishing supplies of land under greater pressure, for both productive use and human settlement. As a result land issues and policies should be key considerations for adaptation planning, so as to strengthen land tenure and management arrangements in risk environments, and secure supplies and access arrangements for land for resettlement and changing livelihood demands(Quan and Dyer 2008).

Climate change mitigation policies that concern the forestry and agriculture sectors and build on economic incentive mechanisms will have to address land and resource tenure in order to foresee, plan and distribute risks and benefits of the mechanisms (FAO 2010).

Zambia has a dual land tenure system: customary tenure and formal title registration. In the customary system the chiefs regulate the allocation of the land. They rule with the consent of their people (Leonen 1999). This system is considered insecure according to western standards but works for the indigenous people. Customary tenure covers 93% of the Zambian area (Angus-Leppan, 1994).It is occupied by 73 tribes, headed by 240 chiefs, 8 senior chiefs and 4 paramount chiefs (Chileshe, 2005). The recognition of customary tenure does not bring about the registration of ownership rights, but only the protection of use and occupancy rights. Customary land is controlled by the chiefs and their headmen but act with the consent of their people. One key aspect of traditional tenure is free access to land by all members of a community. In customary areas in Zambia individual ownership, concurrent interests, and communal interests are recognized. Individual ownership means that the landholder or occupant has more rights and interests in the land than any other person. The individual owns the land for as long as he wishes. Concurrent interests occur where persons, other than the landholder, can go onto someone’s land and use it for their own purposes. Communal interests involve the use of certain tracts of land, which are not individually owned. The role of the chief in most of Zambia is as regulator of the acquisition and use of land but there are important variations in the

73 tribes between the distribution of the “interests of control” and “interests of benefit”. Acquisition in land is possible through the following ways: clearing of virgin bush, as a gift, sale of (improvements on the) land, transfer of land in exchange for goods, transfer of land in exchange of services and marriage (Mvunga 1982). A stranger to the area needs the chief’s permission to settle in the area before acquiring a piece of land. Similarly a chief can prohibit an individual from cultivating in a grazing area. The President of Zambia, however, may alienate any land in the customary area if he takes the local customary law on land tenure into consideration and if he consults the chief and the local authority in the area in which the land to be alienated is situated. The President can thus over-rule the decision of the chief. Without clearly defined systems of administration and demarcation of boundaries, customary Zambia is prone to more land conflicts hindering socio-economic progress.

There is therefore need for land tenure governance that provides secure access to land for local communities provides stability that facilitates long-term planning and investments across scales, from household level farm development to international agreements in view of climate variability and Change. Adaptation also requires increasing emphasis on land use regulation, the governance of land resources, and the delivery of land in safe and secure sites for various uses. This could help preserve the land from degradation through anthropogenic means.

2.4 Pastoralism and Climate Variability

The day-to-day impacts of climate variability such as higher temperature, erratic rainfall and floods are increasing the pastoralists' inability to feed their animals leading to loss of a source of livelihood and thus food insecurity. In the horn of Africa millions of people currently live a lifestyle that is centred on the search for the increasingly scarce pasture and water (Ehrhart 2009). Floods have devastating effects on livelihoods and other human activities. They destroy agricultural crops, disrupt electricity supplies and demolish basic infrastructure such as roads, homes and bridges. Moreover, IPCC (2007) asserts that climates and ecosystems are already changing as a result of human activities and projected warming of 2 to 2.5 ^{o}C will have significant impacts on global agriculture and food prices by 2050. In Southern Africa, it is estimated that by 2050 temperatures will be significantly higher and rainfall will greatly reduce (Zeidler and Chunga 2007) and have serious consequences on food production and security. Droughts are also going to increase. Future climate predictions indicate that the frequency and intensity of dry spells is going to increase in the region (Below *et al.* 2010). Climate variability and change will also cause water stress, land degradation, lower crop yields and increased risk of wild fires, resulting to more than 50 % decline in agricultural productivity (Erhart 2009). These climate change projections if realized, are likely to affect forage and animal production, and ecosystem functioning (McKeon *et al.* 2009). The farmers efforts to subsist on the land are going to be challenged and their resilience will be gradually eroded (Mogotsi *et al.* 2011). Despite increasing vulnerability pastoralism is unique in being able to simultaneously secure livelihoods, conserve ecosystems services, promote wildlife conservation and honour cultural and traditions (ILRI 2006, UNDP 2006). There is therefore need to indentify management strategies that will enable the agro-pastoralists feed their livestock adequately and on a sustainable basis.

2.5 Climate Variation and Feeding of Livestock

Livestock is the fastest growing sector and in some countries accounts for 80% of the GDP in particular in drylands (Nelly 2008). Seventy percent of the 880 million rural poor people living on less the one dollar per day are at least dependent on livestock for their livelihoods and subsequent food security (World Bank 2007). Grasslands the basis for livestock production cover some 70% of the global land area. Good grassland management can increase productivity and food security, provide development opportunities in resource poor drylands and reduce the impacts of drought and climate change. Because of the extensive nature of grasslands they hold enormous potential to serve as one of the greatest terrestrial sinks for carbon. Well managed grasslands could continue to support millions of agro-pastoral people and achieve an estimated one billion tones carbon sequestrated per year (Lal 2004). Livestock plays an important role in carbon sequestration through improved pasture and range management (FAO/LEAD 2006). Well manage grasslands provide other benefits such as increased water infiltration, and retention, improve nutrient cycling associated with organic matter accumulation in the soil as well as increase growth, biomass and diversity of species. Grassland management is thereby also an adaptation strategy for climate change as it reduces the risks associated with prolonged drought periods and unreliable rains.

Grasslands and livestock stewards have many socio-economic barriers to overcome to be able to manage the vast areas of grassland in such a way that they will be productive and sequester carbon. The barriers include among others land tenure/common property issues and privatization and competition from cropping and other land uses which limit grazing patterns and areas, policies which focus on reducing numbers instead of grazing management and the completion of land use for crops include biofuels and low literacy levels among the people. Figure 2.5.1 shows the interaction of some of these components and how they affect the grasslands leading to environmental degradation

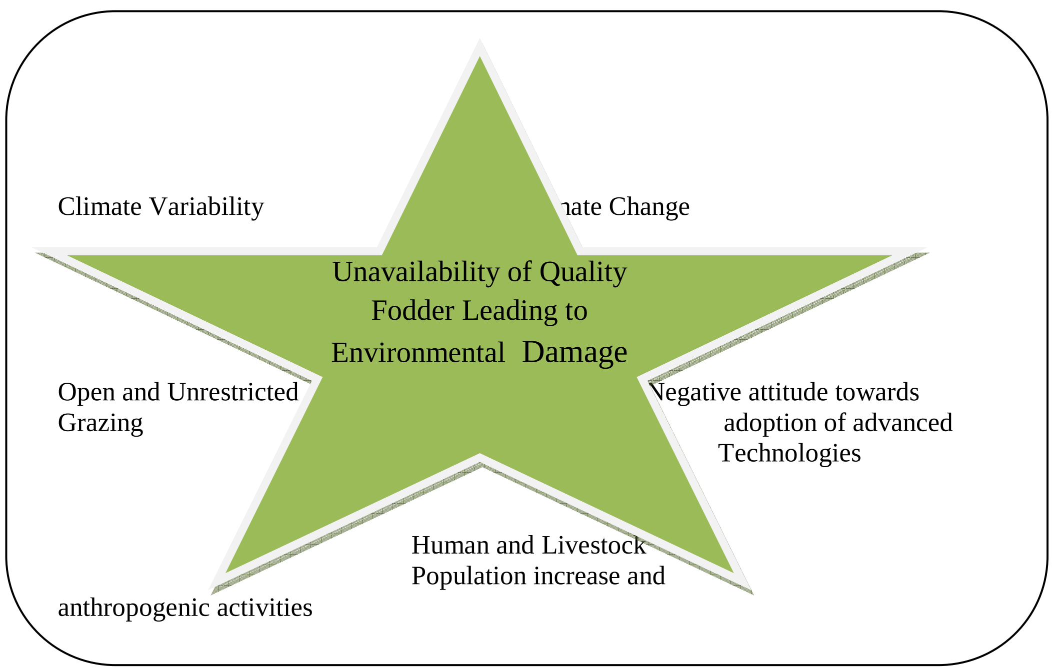


Figure 2.5.1Various components and how they can negatively affect animal feed resources and cause environmental damage. Adapted from Tewari 2006

However, these agro-pastoralists have managed their grassland system for many centuries and have had detailed knowledge of the biodiversity and environment of their grazing lands. Despite the existence of such valuable knowledge, researchers and development experts have previously deliberately overlooked the indigenous knowledge in the evaluation of rangeland (Abate *et al*. 2009). A combination of pastoral indigenous knowledge and modern scientific information may be helpful in providing a better understanding of the environment from the perspective of those utilizing the resources (Ayana and Gufu 2009). For example droughts have the effect of favouring some trees and shrubs while adversely affecting others. (Primefact 2007). Frequent floods and droughts can also cause changes in the composition of the species of forage plants in the area which has an impact on animal production. Disappearance of certain plants due to drought can reduce the biodiversity of plants which can have a negative effect on animal production. Change in climate can also cause invasion of some unwanted pasture species in the grazing areas which can also have a negative effect of the productivity of animals.

There is therefore need to understand the impact of climate variability on the change in the utilisation of the feed resources by the pastoralists to mitigate the negative effects. This will help to know which indigenous forage species are becoming more adaptable and therefore more important for livestock feeding.

2.6 Feeding Strategies in Extreme Weather Conditions.

African pastoralism has evolved in adaptation to harsh environments with very high temporal variability in rainfall (Ellis 1995). Pastoralists have employed strategies such as moving to other areas unused in 'normal' dry season (Morton 2007), keeping multispecies herds to take advantage of different ecological niches and the labour of men, women and children and supplementary feeding in their quest for proper feeding of their animals. Many tropical pastures have a high annual yield of dry matter but annual animal production is seriously limited by the seasonal nature of this production and negative effects of climate variability such as drought.

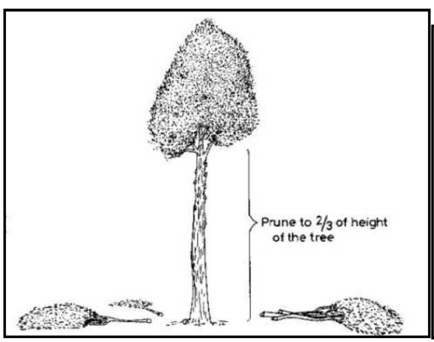
However proper feeding of animals has remained a challenge because of increase in climate variability and their animals are still on poor diets. Feeding animals with poor quality feeds has been associated with increased emission of greenhouse gases particularly carbon dioxide and methane that have been implicated in global warming (Beauchemin *et al.* 2008, 2009). Feeding animals on high quality pasture or balanced rations produce less methane (270 – 350 g methane/cow/day) than those on poor quality pasture or feeds (370 - 450 g methane/cow/day), linking productivity to emission rates (Eckard 2007). To improve the quality of feed given to animals use of locally adapted green fodder legumes and browse trees have been recommended in many parts of the tropics (Simbaya 2002).

2.7 Climate Variation and Browse Feeding to Livestock

Dry season feed resources are the major factor affecting long term livestock numbers in the semi-arid region. Livestock nutrition is the major constraint to sustainable livestock production in drylands especially during the dry seasons (Mnene *et al.* 2004 and Kibet *et al.* 2006). In most semi-arid communal areas browse plays a critical role as livestock feed in the dry season (Sibanda 1986, Magadzire 2002, Ndathi 2012). It is estimated that, in the Sahel, up to 80% of the protein ration is provided by plants of the *Capparaceae* family during the three driest months of the year (Baumer 1992). Promotion of the use of browse is important because the browse is less affected by climatic variation compared to herbaceous species. Natural grasses which form the bulk of the feed resource dry up and lose their high nutritive value and digestibility leading to poor animal performance. Browse trees on the other hand remain green, have higher nutritive value and are still very palatable during the dry season. The leaves, pods and fruits from deciduous browse trees and shrubs are consumed from trees or after they have fallen naturally to the ground (Aregawi *et al*. 2008). Herdsmen can facilitate improved accessibility of leaves, pods and other edible portion of the browse species to livestock during the dry season using sticks or stones or by shaking the browse plants/branches or lopping their branches (Aregawi *et al.* 2008). Integrating browse trees, forage and livestock creates a land management system to produce marketable products while maintaining long-term productivity. Economic risk is reduced because the system produces multiple products, most of which have an established market. Production costs are reduced and marketing flexibility is enhanced by distributing management costs between tree products such timber and livestock components. Comprehensive land utilization provides a relatively good income from livestock sale and selective sale of trees and timber products. Well-managed forage production provides improved nutrition for livestock growth and production. Potential products of the tree component include: saw-timber, logs, firewood, poles, nuts, fruits, ornamental flowers and greenery, mushrooms, organic mulches, and other secondary products.

Management practices of browse trees include pruning, pollarding, lopping and coppicing. This can increase the amount of fodder harvested from the trees. The idea is to cut away branches for fodder and firewood and to improve the potential of the tree to produce more of the desired produce. Different tree species can withstand the harvesting of branches to varying degrees. Pruning is the removal of side branches along the stem of the tree, to about two-thirds the height of the tree, leaving the crown untouched (Figure 2.7.1). Except for harvesting branches for fodder or fuel-wood, trees are usually pruned to reduce their shading effects on adjacent crops and to encourage growth of a straight stem for timber. Pollarding is the cutting back of all branches of a tree several metres from the ground (Figure 2.7.2). The main purposes are to harvest branches and leaves, to stimulate the growth of a new, well-formed productive crown and to produce high-quality timber. The branches can be used for fodder and firewood. Only trees that are able to produce new shoots after cutting should be pollarded.

Lopping is to cut away one or more branches from the trunk or stem of the tree to obtain fodder as well as firewood (Figure 2.7.3). Only small portions of branches should be cut to allow the tree to continue to grow well.   Looping of browse tree in order to provide leaf for livestock is a common practice in arid and semi arid lands. This practice can help to improve the amount of browse during the dry season or extreme weather conditions because the browse trees can regenerate after lopping. Mukungurutse (2002), found out that lopping of browse trees C*ombretum apiculatum* and C*olophospermum mopane* increased re-growth of shoots. Browse trees were lopped at zero, 25%, 50% and 75%and the highest re-growth was found in the 75% lopping. However, (Primefact 2009) suggests that no more than about 60% of tree/shrub foliage be removed and that some tree/shrubs remain unlopped to avoid permanent damage to the trees. In Zimbabwe lopping of branches is carried out in the late dry season to make browse accessible to livestock.



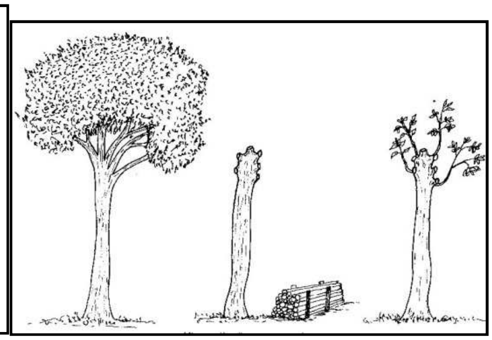


Figure 2.7.1 Prunning

Source: Chileshe and Kitalyi 2002.

Figure 2.7.2Before and after pallarding

Source: Chileshe and Kitalyi 2002.

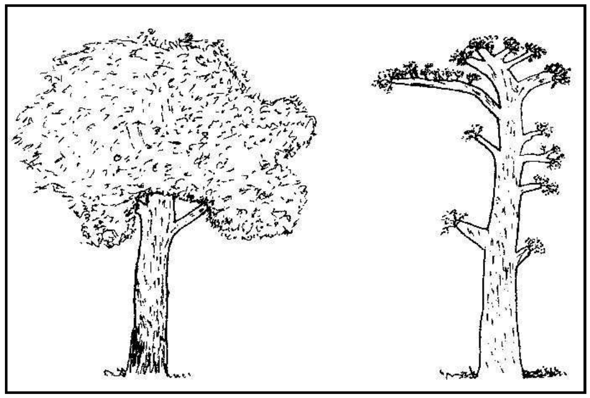
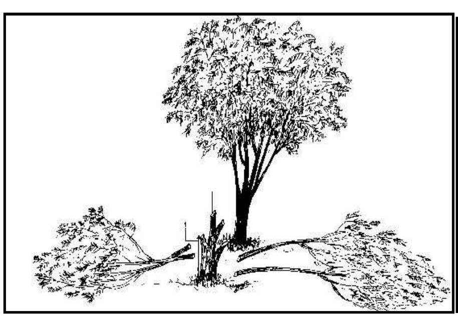


Figure 2.7.3 Before and after Lopping

Source: Chileshe and Kitalyi 2002.



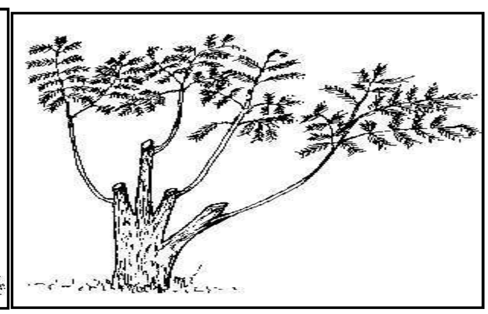


Figure 2.7.4 Coppicing

Source: Chileshe and Kitalyi 2002.

Figure 2.7.5 Re-growth after coppicing

Source: Chileshe and Kitalyi 2002.

2.8 Coppicing

Coppicing is the practice of cutting back a tree to stimulate it to produce new shoots (Figure 2.7.4). This method is ideal for producing forage where livestock are not browsing on the tree directly. Coppicing will enhance a bushy re-growth to produce many branches for fodder (Chileshe and Kitalyi 2002). This practice can help to improve the amount of browse during the dry season or extreme weather conditions because the browse trees can regenerate after coppicing. If coppicing is done also to produce timber, most of the new shoots should be removed, leaving only two or three branches. Coppicing should only be done towards the end of the dry season, or just at the beginning of the rainy season, so the coppiced plants have an opportunity to regrow. Jimu (2010), indicates that some browse species such as *Julbernardia globiflora* coppices well, but trees cut close to the ground (<5cm) produce less coppice growth than plants cut at 1.3 m height. However, very little is known about the effect of coppicing on indigenous browse tree species in Zambia. It is therefore important to look at the effect of coppicing on important indigenous climate adaptable browse trees.

2.9 Nutritive Quality Studies of Local Browse Species

Although leaves of browse trees are an important source of forage for ruminants during the critical period when quality and quantity of pasture herbages are limited there is little information about the nutritive value of leaves. Therefore, it is important to evaluate the potential nutritive value of leaves based on their chemical composition, and *in vitro* dry matter digestibility. Chemical composition can be known by carrying out proximate analysis and parameters such as percentage Dry Matter (DM), Crude Protein (CP), Neutral Detergent Fibre (NDF), Acid detergent Fibre (ADF), and key minerals such as Calcium (Ca) and Phosphorus (P) can be used to measure forage quality. *In vivo* digestibility of many different herbages, have shown that digestibility could be an important index of the relative feeding value of a herbage. However, such measurements are costly when carried out with animals; a technique for the prediction of digestibility by a laboratory method is therefore desirable. Chemical analysis of herbages alone is not adequate for such prediction purposes. The *in vitro* digestion technique is a promising laboratory method for estimating the digestibility of herbage (Tilley and Terry 1963). Reid, Jung and Murray (1964), found dry matter digestibility in *vivo* was closely related to *in vitro* cellulose digestibility, but anomalies in the relationship have been reported by Quicke *et al.* (1959) and Naga and el Shazly (1963).

Therefore, *in vitro* digestion is a biological method in which, under conditions which simulated those within the rumen of a ruminant (anaerobic, near neutral pH, blood heat), small samples of herbage could be digested with crude rumen liquor rich in microorganisms. This laboratory technique for determining the digestibility of dried forages involves incubation first with rumen liquor and then with acid pepsin solution. The rumen inocula, is capable of dealing with the digestible structural carbohydrates, while the digestible protein could, however, be readily removed by a second-stage treatment with acid-pepsin. With this method *in vitro* and *in vivo* results are in very close agreement over a very wide range of herbage samples. Methods based on the use of enzymes rather than rumen liquor have subsequently been used.

It is therefore important measure the chemical composition of browse trees and to carry out *in vitro* digestibility studies in order to determine the level usefulness and effectiveness of the browse species as feed for the animals in extreme weather conditions.

CHAPTER THREE
MATERIALS AND METHODS

3.1 StudyArea

Choma district (16° 40' 0 S, 27° 10' 0 E) and altitude of 1200-1400m in Southern Zambia was chosen because it falls in the semi-arid region of Southern Province which is the driest part of the whole country, the area has often been severely affected by drought, floods, soil erosion. The district lies within the Tonga Plateau an area between two of south central Africa's great rivers the Zambezi and Kafue (Araki 2001). Choma has a tropical wet–dry climate controlled by moist, warm equatorial and maritime tropical air masses characterized by three distinct seasons: hot and dry, from mid-August to mid-November, warm and wet, from mid-November to mid-April, cool and dry, from mid-April to mid-August.

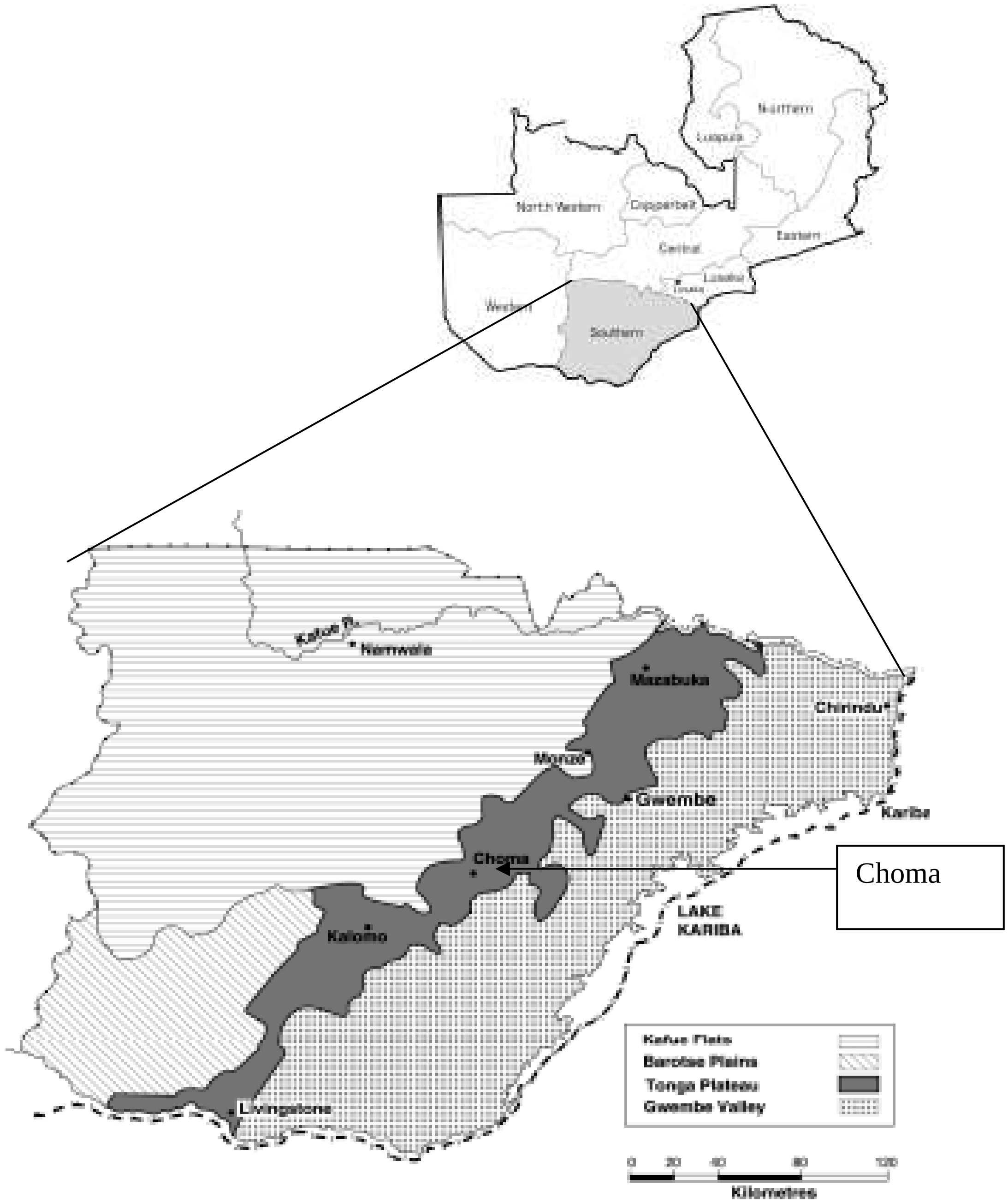


Figure 3.1 Map of Zambia showing location of Choma district. Source; Chileshe and Kitalyi 2002.

The area experiences uni-modal type of rain lasting from November to April. The annual rainfall ranges from 600 to 700mm with an uneven distribution and is generally insufficient with 70% probability of drought. The average monthly temperature is about 22^{o}C with a maximum of 32^{o}C in October and a minimum of 15^{o}C in June (Table 3.1).

Table 3.1 Mean monthly temperatures (^{o}C) for Choma District.

Seasonal Variations	**Temperature (^{o}C)**
Warm wet season (December to February)	
Minimum temperatures	16-17
Average temperatures	21-22
Maximum temperatures	26-27
Cool dry season (May to July)	
Minimum temperatures	4-7
Average temperatures	13-16
Maximum temperatures	23-26
Hot dry season (August to October)	
Minimum temperatures	8-12
Average temperatures	18-22
Maximum temperatures	28-32

Source; Baudron*et al.*2007

The District covers 7,289 sq km (Ellisen 2010) and lies within the Agro-ecological Zones 1 and II. (Figure 3.2). Zambia has been divided into three Agro-ecological

Regions or Zones I, IIa, IIb and III. Region I covers the low rainfall and drought prone areas found in the southern parts the country in which crop production does not do very well. Crop production in agro-ecological Region I is mostly at subsistence level and households depend on food from outside the area to make up for shortages in the part of the year. Maize is grown in Region I but the risk of crop failure is high and the small grain crops of drought tolerant sorghum and bulrush millet are the main cereals.

Livestock are important, and food purchase is often financed by sales of livestock, as well as fish from Zambezi and Luangwa Rivers and Lake Kariba. Region IIa is the most productive for cropping and is the main maize producing area in the country as well as being the main area for cash crops like tobacco and cotton. Region 11b is less productive but has high potential for cassava, rice and cattle. Mangoes and cashew nuts have development potential. Region III is mainly a cassava growing area, and although maize is also grown extensively, yields are limited by the acidic nature of the soils and loss of nutrients by leaching during heavy rains. Coffee, pineapples, and rice are important cash crops.

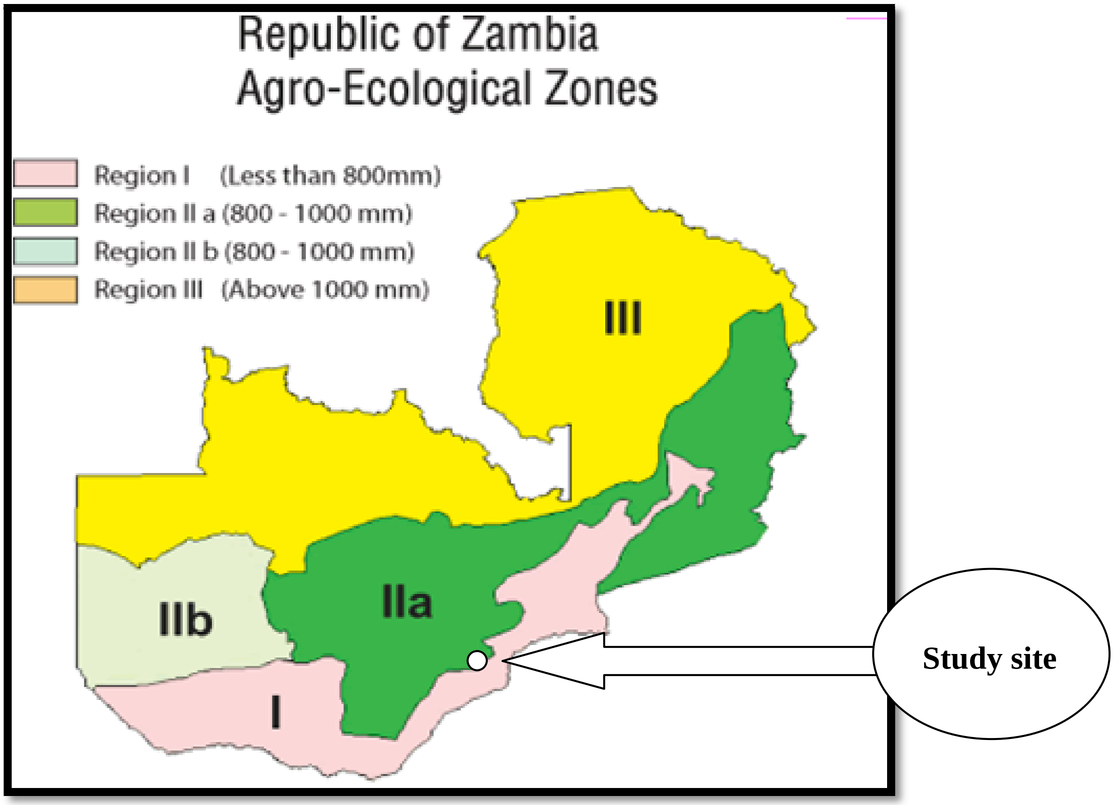


Figure 3.2 The three agro-ecological regions in Zambia.Source; Walubita 2011

The population of the district is 244,180 with a density of 33.5 and an annual population growth rate of 1.9% and has 45,733 households (CSO 2010). The major inhabitants of the study area are the Plateau Tongas who are mainly agro-pastoralists. 84% of the households are small scale subsistence farmers (FAO/FASAZ 2003). The Tonga people live in scattered hamlets, often separated by several hundred metres, and are administratively under the authority of a local headman, who represents the traditional chief. Livelihoods revolve around livestock and crop production, commonly complemented by the use of natural resources. The most common animals kept are cattle, goats and poultry. Household size varies between 4 and 20 family members and polygamy is common. The households are mostly male headed but female- and child-headed households exist as well. HIV/AIDS and malaria cases have had a tremendous negative effect on the traditional family fabric, disorienting many traditional values and farming practices. The prevalent land-tenure system offers rights around the hamlets, cropped fields and planted trees but cropland is used communally after harvest for grazing, gathering and hunting

The Tonga people of southern Zambia practiced a traditional system of grazing reserves where certain areas were reserved for dry season grazing. These areas included seasonally flooded grassland (FAO1990). Ruminant Livestock population stands at 117,406 cattle and 55,832 goats (CSO 2010). Most livestock kept in the district is under the traditional sector with very minimal conventional interventions such as dipping, de-worming and vaccinations. This sector has been greatly marginalized despite the fact that it is the economic backbone of the majority of the population due to constant poor crop yields because of the unfavourable rain pattern.

The vegetation type is miombo woodland (Fanshawe 1966; Chileshe and Kitalyi 2002). The Vegetation is characterized by moderately dense to open stands of deciduous trees, usually over 6 m high Characteristic tree genera are *Brachystegia* and *Julbernardia.* Other common genera are *Combretum, Parinari* and *Pericopsis. Acacia* spp. are found in the high water-table areas of the province. Most notable grass genera are *Andropogon, Brachiaria, Digitaria*, *Heteropogon, Hyparrhenia,* *Hyperthelia*, *Panicum*, *Pogonarthria*, *Tristachya* and *Urochloa (*Chileshe and Kitalyi *2002).*

The part of Choma district which is in ecological zone I, is on flat and steep topography with Haplic Luvisols (FAO 1973) and Haplic Solonetz on the flat land and Dystric Leptosols on the hills and ridges. The Solonetz are highly erodible; arable production is concentrated on bulrush millet (*Pennisetum glaucum*), sorghum and livestock. Food security concerns predominate due to recurrent food shortages. The other part of the district is in ecological zone IIa which constitutes the central plateaux with rainfall of 800 to 1,000 mm. The soils are mainly Haplic, Lixisols Luvisols, Acrisols and other soil types (FAO 1973). These soils are more productive, permanent cultivation of sorghum, maize, groundnuts, cow peas and a range of cash crops including tobacco, sunflower, irrigated wheat, soybean and horticultural crops.

3.2 General Study Methods

This study was done in 2010. Both primary and secondary data were used in this study. The primary data was collected using detailed pre-tested semi-structures questionnaires. Data gathered included the demographic and socio-economic characteristics of the respondents as well as their perception of climate variability. Data on coping strategies as an adaptation to climate variability were also collected. The selecting of the respondents was done with the help Agricultural officers from the Ministry of Agriculture and Cooperatives. Households were selected from Sikalongo Sub-district. Within the sub-district random sampling was firstly used to select villages near Mochipapa Research station after which a sampling unit of agro-pastoral households was drawn from a list of all households in the area. The total number of agro-pastoralists was divided by 60 to obtain the n^{th} value. The first household was then selected randomly from the frame and the subsequent households were selected every after the n^{th} value until when sixty households were obtained. The60 households were interviewed from ten villages namely; Masopo, Siakacheka, Siachimputi, Siabbwenungu, Siamungala, Siazweni, Simuchembu, Simweemba, Kaluwe and Namonza. In addition a Focus Group Discussion and secondary sources of data were used to get a holistic picture of the coping strategies that are used in the area.

CHAPTER FOUR

CLIMATE VARIABILITY, LIVELIHOOD COPING STRATEGIES AND ADAPTATION AMONG AGRO-PASTORAL COMMUNITIES.

(Work published in the Journal of Agricultural and Biomedical sciences JABS Vol. 1 (1), pp 25-29, January –March 2012 ISSN 2226-6410)

Abstract

Agro-pastoralists whose source of livelihood depends mainly on rain-fed agriculture are increasingly facing immense challenges due to climate change and variability. Climate change and variability which manifests itself through increase in temperature and frequent occurrence of floods and droughts are increasing the agro-pastoralists, inability to sustain their sources of livelihood hence their need for coping strategies to adapt to these changes . This study looks at the extent of climate change and variability, the agro-pastoralists perception of climate variability and their coping strategies in extreme weather conditions in Zambia. The study employed semi-structured interviews and Focus Group Discussion technique to collect primary data. Secondary data was also collected. The data sets were subjected to descriptive and trend analysis. The study revealed that there has been an increase of 1.0 ^{o}C in the average annual temperatures over the previous five decades. Variability in the amount of annual rainfall received has increased over the same period while there was a general decline in average annual rainfall received. This is in agreement with most of the farmers' perception that the frequency of floods and drought has increased over the same period. Most of the farmers are coping *with these extreme weather conditions through livestock sales and engaging in non agricultural activities. Non agricultural activities include harvest of products from the forest such as charcoal burning, sale of firewood, carpentry, carving and sale of thatching grass. Others engage in trading, working for others, bee keeping, brick-laying, knitting and fishing. There is need to enhance some of these coping strategies to ensure survival in view of anticipated further increase in frequency, intensity and magnitude of these extreme weather conditions. Harvesting of forest products should be done on a sustainable basis to reduce pressure on the forest and avoid de-forestation.*

Key Words: Extreme weather conditions, adaptation.

4.1 Introduction

Agro-pastoralism provides source of livelihood for millions of people in Sub-Saharan Africa. However the sustainability of this production system is under threat due climate change and variability. The most serious threats have been recurrent droughts and floods. The people have always suffered recurring drought and floods which often lead to food shortages. The situation has been made worse due to the fact that Agro-pastoralists are often ignored in developmental debates and efforts that focus on food security in terms of crop production (Parry *et al.* 1999, FAO 2006, IPCC 2007).

4.1.1 Climate variability

Climate variability which refers to the climate changes taking place around the globe can affect the livelihoods of agro-pastoralists in diverse ways. The day-to-day impacts of climate variability such as higher temperature, erratic rainfall and floods are increasing the pastoralists' inability to feed their animals leading to loss of a source of livelihood and thus food insecurity. Floods have devastating effects on livelihoods and other human activities. They destroy agricultural crops, disrupt electricity supplies and demolish basic infrastructure such as roads, homes and bridges. Moreover, IPCC (2007) asserts that climates and ecosystems are already changing as a result of human activities and projected warming of 2 to 2.5 ^{o}C will have significant impacts on global agriculture and food prices by 2050. In Southern Africa, it is estimated that by 2050 temperatures will be significantly higher and rainfall will greatly reduce (Zeidler and Chunga 2007) and have serious consequences on food production and security. Droughts are also going to increase. Future climate predictions indicate that the frequency and intensity of dry spells is going to increase in the region (Below *et al* 2010). Climate change and variability will also cause water stress, land degradation, lower crop yields and increased risk of wild fires, resulting to more than 50 % decline in agricultural productivity (Erhart 2009). These climate change projections if realized, are likely to affect forage and animal production, and ecosystem functioning (McKeon *et al.* 2009). The farmers efforts to subsist on the land are going to be challenged and their resilience will be gradually eroded (Mogotsi *et al.* 2011) There is therefore need to indentify and enhance coping strategies that will enable the farmers live with these changes instead of dying from them

4.1.2 Livelihood coping strategies and adaptation

Coping strategies are defined as specific efforts, both behavioural and psychological, that people employ to master, tolerate, reduce or minimize stressful events (John and MacArthur 1998). Adaptation refers to the adjustment in natural or human system in response to actual or expected climate stimuli or their efforts which moderate harm or exploits beneficial opportunities (IPCC 2007). These adjustments are intended to reduce the vulnerability of society to changes in the climate system (Kates 2000). Adaptive capacity is the capacity to cope with impacts of climate variability and change (Smit and Pilifosova 2002). Moreover adaptation to changes including climate variability is a dynamic process and should as a survival mechanism display enough flexibility to accommodate new components (UNEP AND ICRAF 2006). In

Zambia the Agro-pastoralists have not been spared from theses extreme weather conditions. MTENR 2007, reported that in Zambia the increase in frequency, intensity and magnitude of climate variability over the past two decades have adversely impacted on food security, water security, water quality, energy and sustainable livelihoods for the rural communities. Using the Zambian case this study examines the magnitude climate variability the agro-pastoralists' perception of climate variability and the coping and adaptive strategies that they employ when faced with this vice.

4.2 Materials and Methods

4.2.1 Study area

The study was carried out in the Southern Region of Zambia in Choma District. The district lies within the Tonga Plateau an area between two of south central Africa's great rivers the Zambezi and Kafue (Araki 2001) The area experiences uni-modal type of rain lasting from November to April. The annual rainfall ranges from 600 to 700mm with an uneven distribution and is generally insufficient with 70% probability of drought. The average monthly temperature is about 26^{o}C with a maximum of 32^{o}C in October and a minimum of 15^{o}C in June. The vegetation type is miombo woodland (Fanshawe 1966; Chileshe and Kitalyi 2002). The major inhabitants of the study area are the Plateau Tongas who are mainly agro-pastoralists.

4.2.2 Data collection

This study was done in 2010. Both primary and secondary data were used in this study. The primary data was collected using detailed pre-tested semi-structured questionnaires as earlier described. Data gathered included the demographic and socio-economic characteristics of the respondents as well as their perception of climate variability. Data on coping strategies as an adaptation to climate variability were also collected. The selecting of the respondents was done with the help Agricultural officers from the Ministry of Agriculture and Cooperatives. Households were selected from Sikalongo Sub-district. Within the sub-district random sampling was firstly used to select villages near Mochipapa Research station after which a sampling unit of agro-pastoral households was drawn from a list of all households in the area. Sixty farmers were interviewed from ten villages namely; Masopo, Siakacheka, Siachimputi, Siabbwenungu, Siamungala, Siazweni, Simuchembu, Simweemba, Kaluwe and Namonza. In addition a Focus Group Discussion and secondary sources of data were used to get a holistic picture of the coping strategies that are used in the area.

4.2.3 Climate data

The long term temperature and rainfall data was collected from the Meteorological Department of the Ministry of Environment and Natural Resources. This data came from Mochipapa Research field station which is located within the study area. The data collected was for a period of 50 years, from 1960 to 2010.

4.2.4 Data analysis

Data were analyzed using GenStat Discovery Edition 3 software programe. Graphs were used to present climate data. Data from the questionnaire survey were first coded and entered using Microsft Excel. Frequencies were calculated using simple descriptive statistics for respondents demographics, socio-economic characteristics and other related variables. The Coefficient of rainfall variability was calculated using the following formula;

$$C.V = \left(\frac{SD_i}{R_i} \right) X\ 100$$

where CV = Coefficient of Rainfall Variation

SD = Standard Deviation of Annual Rainfall

R = Annual Rainfall Average

i = Subindex ranging from 1 -10 for each particular year of a decade.

4.3 Results and Discussion

4.3.1 Age and gender distribution of the respondents

The study revealed that 94.92% of the agro-pastoralists in the study area were male headed and 5.08% female. The majority of the agro-pastoralists were headed by members older than 40 years 74.14%. Of the respondents 68.96% were in monogamous marriages, 29.31% in polygamous marriages whilst 3.44% were single and female. The fewer female headed households were as a result of polygamy. The females are normally married off even to already married men as per Tonga tradition. They have had a belief that having more than one wife and a large family is a way of having more labour to engage in agricultural production thereby increasing food production to ensure food security. Polygamous marriages and multiples wives in the homes make them free to engage in food security activities to sustain the family unit. This is contrary to what Ogunsumi and Ogbosuka(2009) found out that the number of wives and the type of marriage are not related to maintaining food security. The level of education of the family household was high as more than 90% of them have had some formal education. The high level of education is important as it encourages some level of planning and decision making (Mogotsi *et al.* 2011). That means that it would be easy for the farmers to comprehend issues of climate variability and are more likely to make rational decisions. Household sizes were higher, 16 individuals in polygamous marriages compared to 9 in monogamous marriages and 10 in singles. The large size of households is common in agro-pastoral communities because of the high labour requirement of farming operations.

4.3.2 Agricultural activities

All the respondents were involved in mixed farming which involves the growing of crops and the rearing of livestock. The main crops grown are maize as the staple crop, groundnuts, sweet potatoes and cowpeas. The major livestock reared are cattle, goats and chickens with cattle being the most important as per Tonga Tradition. The other agricultural activities practiced by the farmers are gardening (growing of vegetable), fruit growing, bee keeping and fishing (see Figure 4.1). All of these agricultural activities have a direct relation to climatic conditions and any climatic deviation from the normal would adversely affect production.

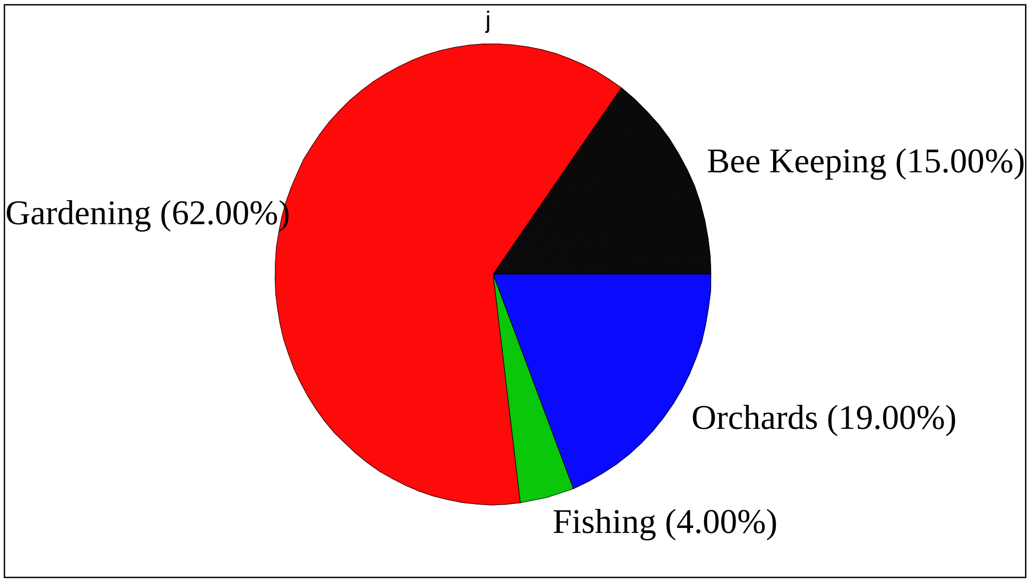


Figure 4.1 Other agricultural activities practiced by the agro-pastoralists

4.3.3 Climate data from the study area

Past climatic date collected from the area covered a period of 50 years, from 1960 to 2009 as shown in Figure 4.2. The data revealed that there has been temperature variability as well as a general increase in the average annual temperatures. The average annual temperature were 18.755, 19.10, 19.61, 20.08 and 19.77 ^{o}C for the decades ending in 1969, 1979, 1989, 1999 and 2009 respectively, (Figure4.3). This shows an increase of 1.0 ^{o}C. between 1960 and 2009. This is slightly higher than the empirical evidence that shows that a warming of approximately 0.7^{o}C over most of Africa during the 20th Century (IPCC 2007). IPCC 2007 indicated that a 3 ^{o}C temperature increase could lead to 0.4 to 1.8 billion more people at risk of water stress. The population at risk due to increased water stress in Africa is projected to be between 75-250 million people by 2020 and 350-600 million by 2050. This increase in average temperatures would cause a reduction on water availability which will impact negatively on livelihoods of the people since they depend on rain fed agriculture. Increase in temperature can also cause decrease in livestock productivity directly and indirectly through changes in the availability of feed and fodder. There is also increase incidence of pest attacks and manifestation of vector and vector borne disease.

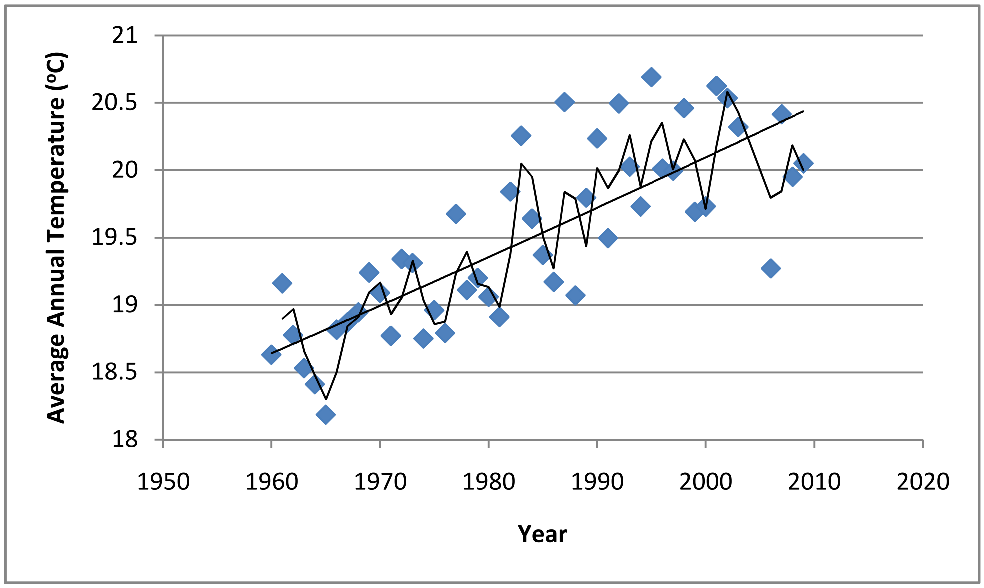


Figure 4.2. Change in mean of Average Annual Temperatures (°C) in Choma District

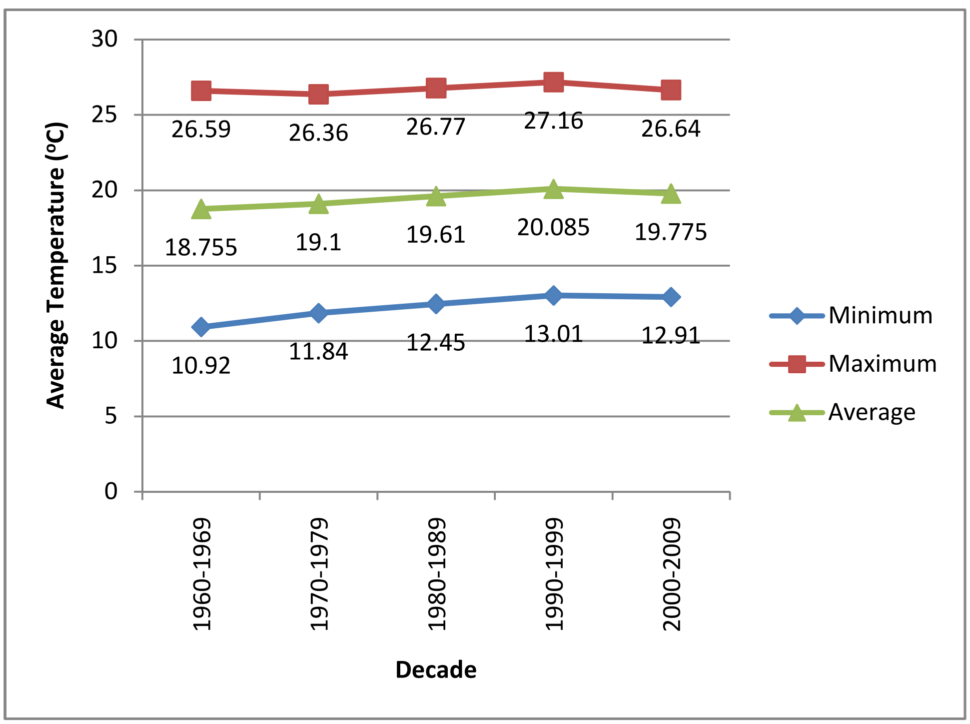


Figure 4.3. Average Temperature (°C) for each Decade in Choma District

The rainfall data revealed that there has been increased variability in the amount of annual rainfall received from 1973 to 2009 as shown in Figure 4.4. There is less variability shown from 1951 to 1972. This increased variability is an indication that the frequency of floods and droughts has increased from 1973 to 2009 compared to the period 1951 to 1972. Decadal rainfall averages show an increase from 810.13 mm to 851.75 mm in the two decades from 1960 to 1979 and then reduced to 775.28 mm in 1989 as shown in Figure 4.5. There was further reduction to 714.49mm to 1999. In the decade from 2000 to 2009 there was an increase to 813.59mm. This shows that there has been some floods in certain years and some droughts in other years. The trend line also shows that there has been a general decrease in rainfall over the whole period of six decades, Figure 4.4. Hume *et al.* (2001) found a decrease in precipitation by about 2.4 ± 1.3 per decade in tropical rainforest of Africa since the mid 1970s. If this trend continues then there is going to be increased water stress as the demand from water increases due to increasing human and livestock population. Reduction of water will lead to loss of food production capacity due to decreasing yields and hence the threat to food security. IPCC 2007 estimates that by the 2080s, parts of arid and semi-arid lands in Africa will to increase by 5-8%.

It is therefore importance to ensure that climate change reversal measures are put in place to avoid acceleration of climate change driven problems such as desertification processes and food insecurity in the region. These measures include reduction in deforestation and burning of grasslands, fossil fuels and other wastes. These measures reduces the amount of carbon dioxide one of the green house gases which is emitted into the atmosphere and causes climate change. Feeding the ruminant high quality pastures reduces methane emission (Leng 1993). If the ruminants are fed poor pastures they produce more methane which is one of the green house gases that cause climate change. Animals on high quality pasture or balanced rations produce less methane (270 – 350 g methane/cow/day) than those on poor quality pasture or feeds (370 - 450 g methane/cow/day), linking productivity to emission rates (Eckard 2007).

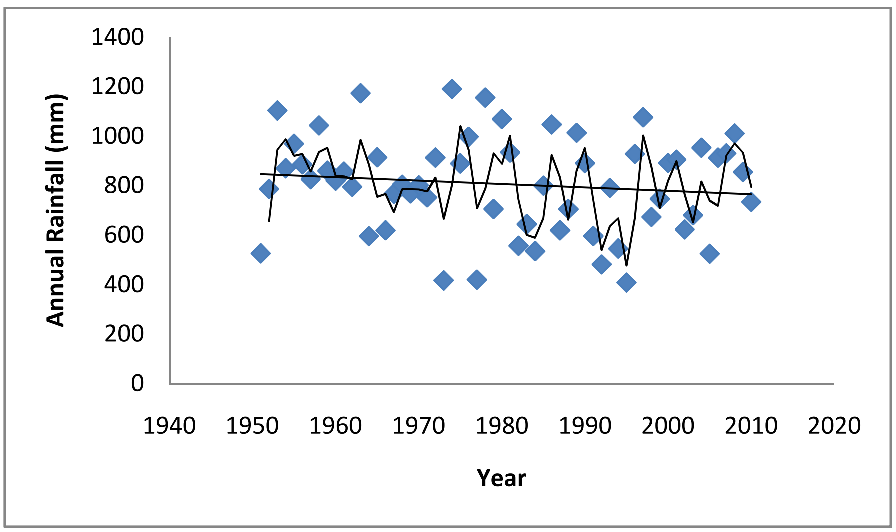


Figure 4.4. Variations in Annual Rainfall (mm) in Choma District

Coefficient of rainfall variability for each decade was;1951-1960 =17.23%, 1961-1970=18.78%,1971-1980=30.87%, 1981-1990 =23.13%, 1991-2000 =28.23 and 2001-2010 =18.88%

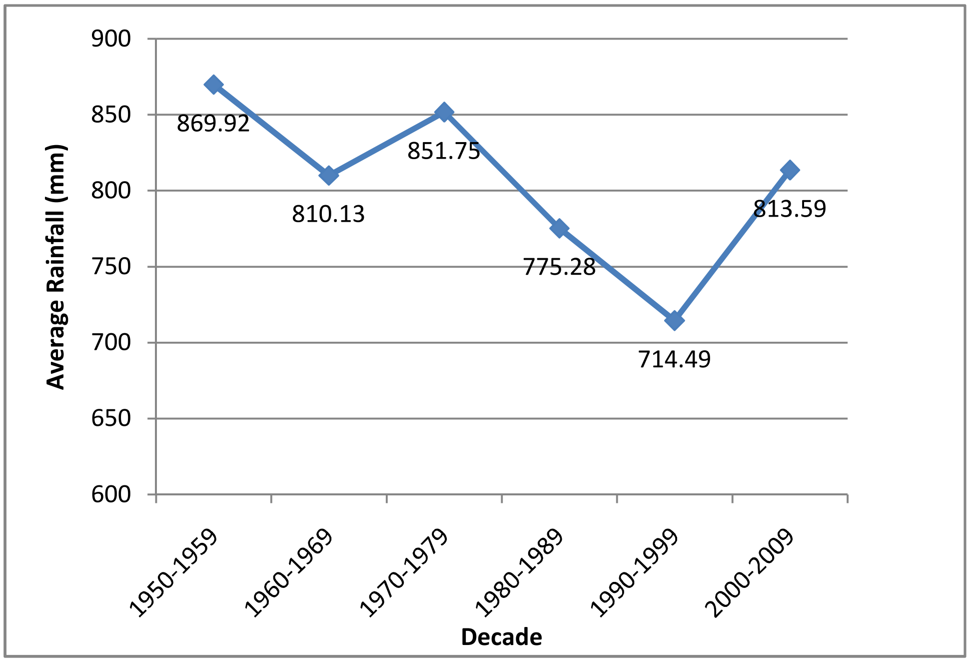


Figure 4.5. Average annual Rainfall in Each Decade in Choma District

4.3.4 Perceptions of climatic change and variability

As shown in Figure 4.6, 98.33% of the respondents indicated that there has been climate change over the past 30 years. Most of the respondents (85.00%) used the increase in rainfall as the indicator for climate change compared to decrease in rainfall (18.33), late onset of rains (5.00%), the weather becoming hotter (1.67%) and the weather becoming colder (3.33%) (Figure.4.7). The highest response for the increase in rainfall could have been due to the fact that the people had experienced unprecedented floods the rainy season just before the survey was conducted.

The respondents states different opinions concerning climatic variability and extreme weather conditions. 61.675% indicated that there is in increase in climatic variability in terms of increased frequency of floods and droughts, Figure 4.8. 13.33% indicated that floods and droughts have reduced, 1.76% said there was no change and 1.76% were not sure, Figure4.8. These perceptions by the agro-pastoralists are in agreement with the climatic data from the same area which show an increase in temperature and rainfall variability. This is because farmers have been experiencing regular occurrence of drought and floods. This is in agreement with Rao *et al.* (2011) who indicated that farmers are well aware of the general climate in their location and its variability. The farmers are already adjusting to their way of doing things as a result of this perception. This includes selecting of plant and animal species that survive well in adverse weather conditions. The farmers do this by using early maturing crop varieties, adjust the planting dates and choose to put their crop fields in valleys, slopes, or on uplands areas. They also keep a variety of animals such as cattle, goats and chickens. Infact a number of Non-governmental Organisations such as Land O Lakes and World vision have been promoting the rearing of goats because they are adapted to survive well in adverse weather conditions. A progressive shift from cattle to small ruminants has been observed which is viewed as a strategic move since small stock reproduce much faster than cattle and are more hardy, less costly and easier to feed (Mortimore and Adams 2001).

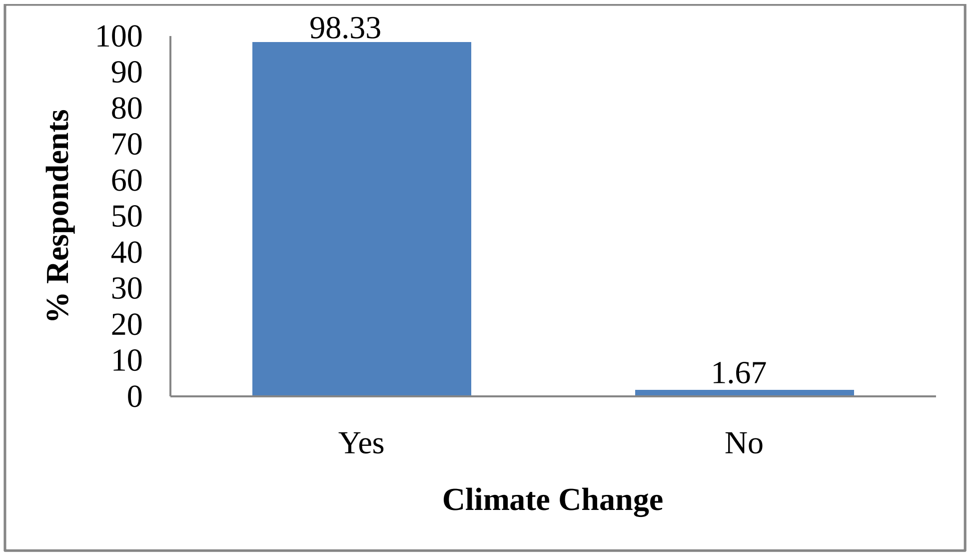


Figure 4.6 Evaluation of climate change in Choma District over the past 30 years

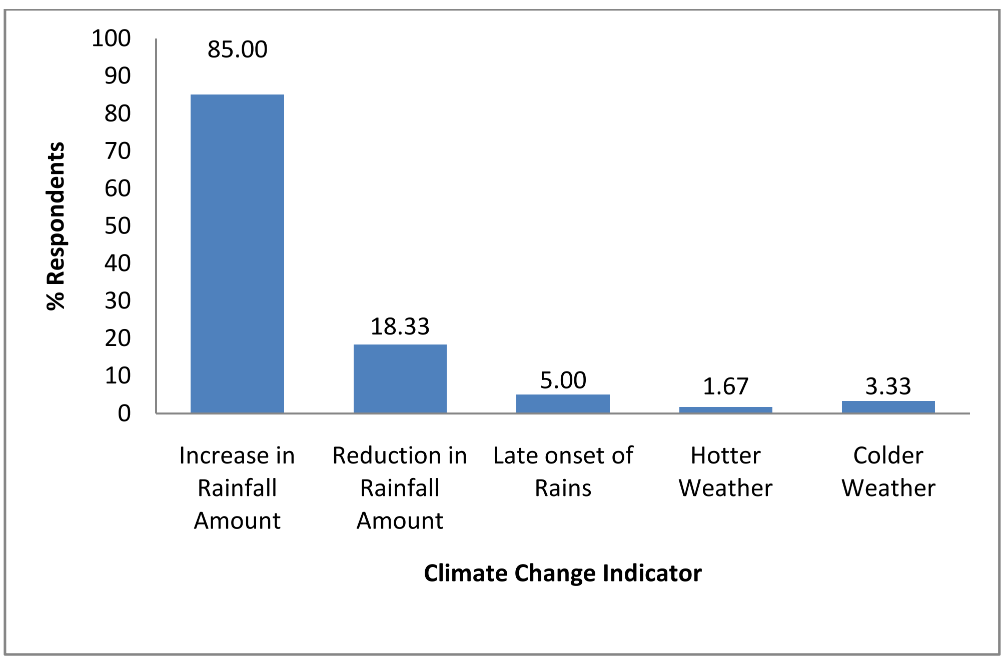


Figure 4.7. Comparisons of climate change indicators in Choma district

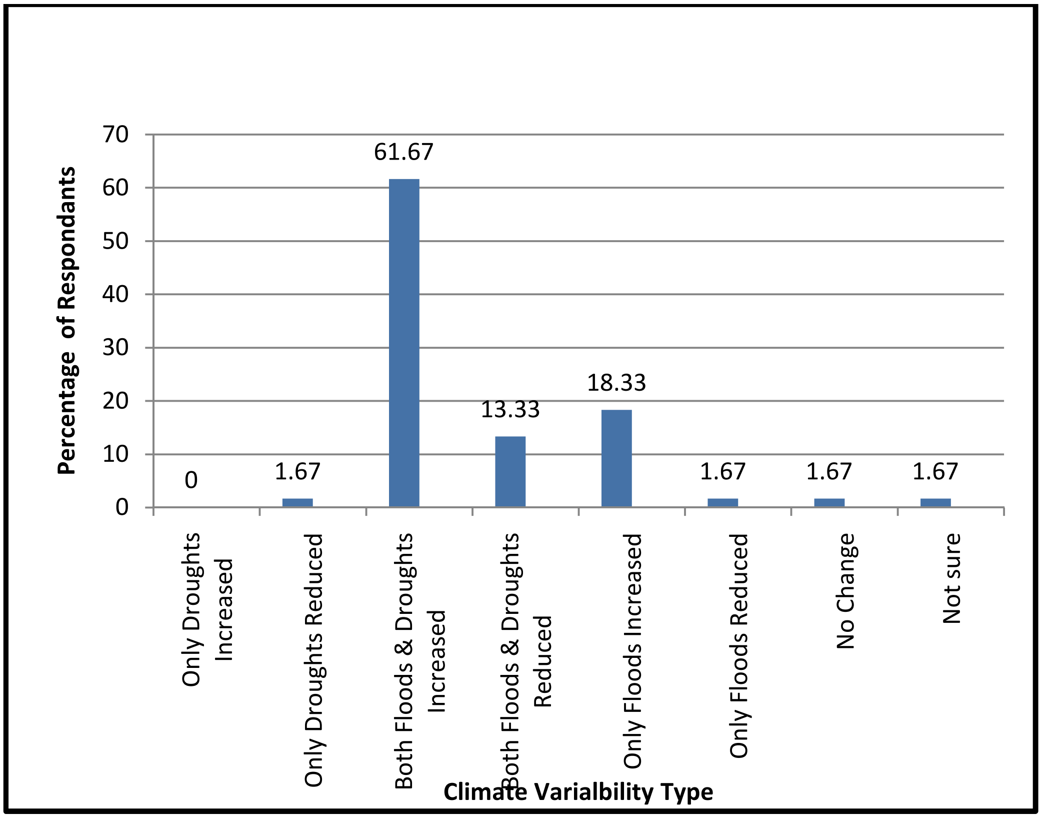


Figure 4.8**.** Pastoralists Perception of Climate Variability Type

4.3.5 Livelihood adaptive strategies in extreme weather conditions

Households vary livelihood strategies when faced with extreme weather conditions (Ellis 1998; Valvidia and Quiroz 2003) and is influenced by linkages inside and outside agriculture (Bebbington 1999). Table 4.1 shows the variety of the livelihood strategies employed in Choma district and are categorized as agricultural related and non-agricultural. The agricultural livelihood practices for the pastoralists were livestock and crop sales, vegetable growing and sale of citrus fruits. The main non agricultural activities were charcoal burning and sale of firewood, trading, working for others and carpentry. It is important to note that there is diversification both within the agricultural and non agricultural coping strategies. Diversification between and within crops and livestock reduces the farmers vulnerability to climate variability more than if it takes place at one farming level, crop or livestock level. Vulnerability to climate variability is further reduced with incorporation and diversification of non agricultural activities that are not directly dependent on climatic conditions. Therefore the non agricultural activities are extremely important in extreme weather conditions. The need for alternative sources of income outside agriculture is real and calls for diversification of livelihood strategies ((UNEP AND ICRAF 2006)

Among the non agricultural activities the most important were charcoal burning, sale of fire wood, carpentry, carving and sale of thatching grass as indicated by the highest value of 53.15%. The least practiced activities are collection of wild fruits and fishing as indicated by 1.69% of the respondents. All those activities have an important effect on the forests.

Table 4.1 Agricultural and Non-agricultural livelihood strategies of agro-pastoralists during extreme weather conditions.

Livelihood practice	Respondents %	Ranking
Agricultural		
Sale of Livestock	93.33	1
Sale of Crops	31.67	2
Vegetable Growing	23.33	3
Sale of Citrus Seedlings	3.33	4
Non- agricultural		
Products from Forest (Charcoal burning, sale of firewood Carpentry/Carving, Sale of Thatching Grass)	53.15	1
Trading	30.51	2
Working for Others	13.56	3
Bee Keeping	6.78	4
Bricklaying	3.39	5
Knitting	3.39	5
Wild fruit collection	1.69	6
Fishing	1.69	6

4.3.6 Climate variability and harvest of forest products for survival

In Africa two thirds of the population of approximately one billion people, rely directly or indirectly on forests and woodlands for their livelihoods (The World Bank

2004). Tropical forests hold several goods and services used by forest dependent people as safety nets to transverse difficult periods of resource supply (Nkem *et al.* 2010). Communities are able to cope with climate impacts using natural resource base in the forest ecosystem that provides livelihood goods and services (COFCCA 2011). Forest resilience will ensure the continuous provision of these goods and services as the lifeline of the poor majority who directly depend on them. In the Choma agro-pastoral community charcoal burning, carpentry, curving, selling of firewood, sale of thatching grass and collecting of wild products are important activities farmers engage under extreme weather conditions (Figure 4.9). These could cause a negative impact on the forest with increased climatic variability if not done sustainably. Bonan (2008) and Eastaugh (2008) have noted that forests are expected to face significant pressure from climate change over the next century which will potentially disrupt the important ecological, economic, social, and aesthetic services that forests provide. Therefore, more extreme weather conditions will put more pressure on the forest which could lead to serious deforestation and land degradation. Since forests and trees are part of the strategy to cope with climate change it is important to embrace forests use so that it becomes part of the climate strategy for adaptation. It should be done in a sustainable manner by not over harvesting and by encouraging re-planting of the indigenous trees There is also need to encourage livelihood strategies that do not impact directly on the forest and to ensure sustainable use of the forest. Coping strategies such as bee keeping and trading do not impact negatively on the forest. This will help to mitigate the negative effects of climate variability and climate change on forest use. Trading is the second most important non-agricultural livelihood strategy. Some of the pastoralists are involved in trading in groceries, small farm implements and other merchandise which they can get from nearby towns. Trading and business activities within the confines of the village territory help supplement farm driven income (Batterbury 2001; Mortimore and Adams 2001). This should be encouraged because it does not cause harm to the forest.

There is also need to bear in mind that, linkages between issues of climate change and variability and questions of land tenure are multiple, complex and indirect. However, the effects of climate change and variability are felt through changes in natural ecosystems, land capability and land use systems. Increasingly, these changes will place diminishing supplies of land under greater pressure, for both productive use and human settlement. As a result land issues and policies are key considerations for adaptation planning, which will need to strengthen land tenure and management arrangements in risk environments, and secure supplies and access arrangements for land for resettlement and changing livelihood demands.

 Plate 4.1: Transportation of charcoal to market. Source; Author.	 Plate 4.2: Sale of charcoal by the road side. Source; Author.
 Plate 4.3: Sale of Craft such as wooden stools pestle and mortar. Source; Author	 Plate 4.4: Sale of small wooden tables Source; Author.
 Plate 4.5 Sale of Thatching Grass. Source; Author.	 Plate 4.6 Sale of special types of pestles and mortars. Source; Author.

4.4 Conclusions

From this study, the conclusions are that; there has been an increase in climate variability over the last five decades in the study area. Farmers have the right perceptions concerning climate variability and extreme weather conditions and is seen in the way the carry out their faming activities and adaptation to the extreme conditions. Livestock sales and use of forestry resources are the key coping and adaptive strategies to climate variability in the study area. There are challenges associated with some of the alternative strategies such as charcoal burning which leads to deforestation.

4.5 Recommendations

The recommendations from this study were that; there is need to promote the use of climate data so that the agro-pastoralists can make informed decisions concerning alternative livelihood strategies. There is also need to encourage alternative livelihood strategies to climate variability so as to reduce the potential negative impact of excessive exploitation of the forest and forest products particularly deforestation and associated land degradation. This will ensure sustainable utilization of the natural resources for the long term benefit of the farmers. The challenges associated with some of the alternative strategies such as charcoal burning which leads to deforestation should be mitigated by promotion of national reforestation programmes. There also need to encourage continued provision of secure land tenure arrangements to enhance households and communities capacities to sustainably adapt to climate change impacts on livelihoods and food security.

CHAPTER FIVE

CLIMATE VARIABILITY,AND ADAPTIVE UTILISATION OF BROWSE TREES FOR IMPROVED LIVESTOCK PRODUCTION AMONG AGRO-PASTORAL COMMUNITIES IN SOUTHERN ZAMBIA.

(Work published in African Journal of Environmental Science and Technology Vol. 6(7), pp. 267-274, July 2012 DOI: 10.5897/AJEST11.329   ISSN 1996-0786 ©2012 Academic Journals. Available at <u>http://www.academicjournals.org/ajest/abstracts/abstracts/abstract%202012/July/Chibinga%20et%20al.htm)</u>

Abstract

Agro-pastoralists whose source of livelihood depends on rain-fed agriculture are very vulnerable to ecological disturbance due to increasing climate variability. They are unable to adequately feed their animals in times of extreme weather conditions of floods and droughts thereby causing a disruption in their major source of livelihood. This study analysed the feeding strategies employed by Agro- pastoralists in Southern Zambia and identify important browse species used in extreme weather conditions in order to improve their utilization for improved livestock production. The major livestock feeding strategies during droughts include browse utilization, dambo grazing, grazing along streams and supplementary feeding while during floods upland grazing and browse grazing were the main strategies. However, most of the agro-pastoralists do not practice pasture management and fodder conservation for their animals. Of the twenty one (21) tree browse species identified by the agro-pastoralists seventeen (17) species have been found to be important during droughts and eight (8) during floods. Most of the agro- pastoralists neither knew how to plant these browse species nor how to manage them for better and *sustainable use in feeding their animals. Therefore the agro- pastoralists in the study area need to take up management and feed conservation measures for their animals. Deliberate effort should be made to teach the agro- pastoralists how to plant and manage the important browse species that are suitable in extreme weather conditions. This will enhance productive use of the browse species for improved animal feeding to ensure food security among the agro-pastoralists.*

Key Words: Extreme weather conditions, adaptation, browse species, agro-pastoralists

5.1 Introduction

Pastoral systems provides an important source of livelihood to many people in the world. About 40 million people and almost half of them being African pastoralists depend on almost entirely on livestock for their livelihoods (AFORNET 2005). Sustainability of this production systems has been facing a lot of challenges in Africa especially with reference to availability of adequate animal feed resources. In the horn of Africa millions of people currently leave a lifestyle that is centred on the search for the increasingly scarce pasture and water (Ehrhart 2009). Over the years climate variability and change has impacted negatively on the ability of the local ecosystems to faithfully meet the ever increasing demand for feed resources for their animals.

5.1.1 Pastoralism and climate variability.

Climate variability refers to variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events (USAID 2007). Climate variation manifests itself in extended drought, floods and conditions that result from periods of El Nino and La Nino events. Over the years the frequency of the climate variation in terms of temperature and rainfall has been increasing. It is estimated that by 2050 temperatures will be significantly higher and rainfall will greatly reduce in Southern Africa (Zeidler and Chunga 2007). These climate projections are going to affect forage and animal production, and ecosystem functioning (McKeon *et al.* 2009). Climate change and variability will also cause water stress, land degradation, lower crop yields and increased risk of wild fires, resulting more than 50 % decline in agricultural productivity (Ehrhart 2009). The pastoral communities and their livestock are very vulnerable to these ecological disturbances which often result in food insecurities and shortages (SoRPARI 2005). They are unable to feed their animals on good quality feeds. In Zambia the mean temperature computed for the previous thirty years for the agro-ecological zones for three periods, November to December. January to February and March to April indicate that the summer temperature is increasing at the rate of $0.6^{o}C$ per decade, which is ten times higher than the global or southern African rate of increase in temperature, Centre for Environmental Economics and Policy in Africa (CEEPA 2006). The annual rainfall data for the 14 years from 1990/1991 to 2003/2004, show that at least ten years in each agro-ecological zone had below normal rainfall. The southern zone has experienced more severe dry seasons than the central zone in the last 20 years (CEEPA 2006). The Agro-pastoralists in Zambia have not been spared from theses extreme weather conditions. Ministry of Tourism Environment and Natural Resources (MTENR) reported that in Zambia the increase in frequency, intensity and magnitude of climate variability over the past two decades have adversely impacted on food security, water security, water quality, energy and sustainable livelihoods for the rural communities(MTENR, 2007).

5.1.2 Feeding strategies in extreme weather conditions.

African pastoralism has evolved in adaptation to harsh environments with very high temporal variability in rainfall (Ellis 1995). Pastoralists have employed strategies such as moving to other areas unused in ‘normal’ dry season (Morton 2007), keeping multispecies herds to take advantage of different ecological niches and the labour of men, women and children and supplementary feeding in their quest for proper feeding of their animals. However proper feeding of animals has remained a challenge because of increase in climate variability and their animals are still on poor diets. Feeding animals with poor quality feeds has been associated with increased emission of greenhouse gases particularly carbon dioxide and methane that have been implicated in global warming (Beauchemin *et al*, 2008, 2009). Feeding animals on high quality pasture or balanced rations produce less methane (270 – 350 g methane/cow/day) than those on poor quality pasture or feeds (370 - 450 g methane/cow/day), linking productivity to emission rates (Eckard 2007). To improve the quality of feed given to animals use of locally adapted green fodder legumes and browse trees have been recommended in many parts of the tropics (Simbaya 2002).

In Zambia there is lack of knowledge concerning the pastoral production systems and their adaptive use of browse trees in view of climate variability. The type of forage species that have higher adaptation to climate variability in these rangelands need to be given priority. For example droughts have the effect of favouring some trees and shrubs while adversely affecting others (Primefact 2007). In most arid and semi-arid areas browse play a critical role as livestock feed in the dry season. Trees produce leaves, shoots and fruits which are a source of nutritious livestock feed. Promotion of the use of browse is important because the browse is less affected by climatic variation compared to herbaceous species. The rangeland ecosystem needs to be re-examined in view of climate variability and the need to adequately provide animal feed resources

In view of the above, this study was conducted to determine the feeding strategies employed by agro-pastoralists in Southern Zambia in extreme weather condition and to identify important browse species for use so as to improve their utilization for improved livestock production.

5.2 Materials and Methods

5.2.1 Study area

The study was carried out in Choma District in Southern Province, Zambia. Southern province has the largest number of cattle and goats of all Zambia's provinces, comprising 33% and 31% of the traditional herds respectively (CSO 2009). Choma district lies within the Tonga Plateau an area between two of south central Africa's great rivers the Zambezi and Kafue (Araki 2001). It has a population of 244,180 inhabitants and 24,321 households (CSO 2011). The area experiences uni-modal type of rain lasting from November to April. The annual rainfall ranges from 600 to 700mm with an uneven distribution and is generally insufficient with 70% probability of drought. The average monthly temperature is about 26^{o}C with a maximum of 32^{o}C in October and a minimum of 15^{o}C in June. The vegetation type is miombo woodland (Fashawe 1966; Chileshe and Kitalyi 2002). Characteristic tree genera are *Brachystegia, Fulbernardia, Combretum, Pinari, Pericopsis* and *Acacia* (Chileshe and Kitalyi 2002). The major inhabitants of the study area are the Plateau Tongas who are mainly agro-pastoralists. The majority of the households in the district depend on agricultural related activities for their livelihood including crop production and livestock rearing. Over 90 % of the livestock are managed extensively depending entirely on *in situ* grazing in the rangelands for nourishment. 84% of the households are small scale subsistence farmers (FAO/FASAZ 2003).

5.2.2 Sources of data

This study was done in 2010. Both primary and secondary data were used in this study. The primary data was collected using detailed pre-tested semi-structured questionnaires as earlier described. Data gathered included the livestock ownership, feeding strategies of the livestock, forage management, and important browse species in extreme weather conditions. Human, cattle and goat population in the district was collected from the District Agricultural Office in the Ministry of Agriculture and Cooperatives.

5.2.3 Data analysis

Data were analyzed using GenStat Discovery Edition 3 software programe. Data from the questionnaire survey were first coded and entered using Microsft Excel. Descriptive statistics were used to describe the respondents demographics, socio-economic characteristics and other variables in the production system.

5.3 Results and Discussion

5.3.1 Age and gender distribution of the respondents

The demographic and socio-economic variables of the respondents in the study area have been reported in Chapter 4.

5.3.2 Agricultural activities

All the respondents were involved in mixed farming which involves the growing of crops and the rearing of livestock. The main crops grown were maize the staple crop, groundnuts, sweet potatoes and cowpeas. Livestock rearing is important for rural households in Choma district and mainly involves poultry (100%), goats (81.36%) and cattle (100%). Goat and cattle rearing is higher than what was quoted in FAO/FASAZ (2003), who found 54% and 49% of all the households interviewed to be involved in goat and cattle rearing respectively. The increase has been due to deliberate government efforts through the cattle restocking programme. The cattle restocking programme was introduced in 2003 to restore breeding stock and increase animal draught power (IRIN 2004 and Mulemba 2009) and the Animal Disease Control Programme to preserve the current population of livestock. Goat rearing has also increased because a number of Non-governmental Organisations such as Land O Lakes and World Vision have been promoting the rearing of goats because they are adapted to survive well in adverse weather conditions. Goats also reproduce much faster than cattle and are more hardy, less costly and easier to feed (Mortimore and Adams 2001).

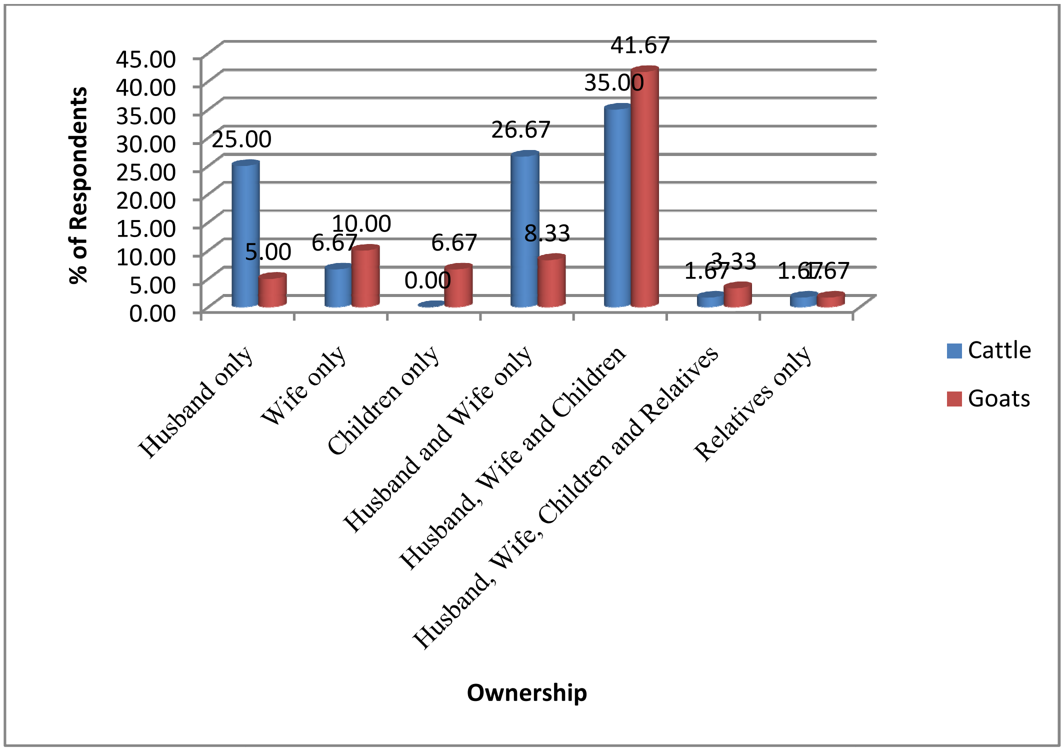


Figure 5.1 Cattle and Goat Ownership

5.3.3 Cattle and goat ownership

Most of the livestock is owned by the nucleus family (Figure 5.1) 41.67% for goats and 35.00% for cattle. Ownership of cattle is four times higher for the husbands (25.00%) compared to wives (6.67) % while the ownership of goats among the wives is two times higher (10.00% compared to husbands 5.00%). This is because traditionally ownership of cattle has been more important among men than women. Ownership of goats is higher among women because there has been deliberate promotion of goat keeping to women by Non Governmental Organisations(NGO). This has been done as a way of empowering women with some wealth. Promotion of goat keeping is very important adaptability strategy especially in times of high climate variability because goats are able to withstand harsher climate compared to cattle. The agro-pastoralists are still practicing the keeping animals from other relatives. This is one way of adapting to harsh climate because if there is drought in one region then the animals kept by relatives in other region which are not hit by drought would survive and thus, the owners will not lose all the animals. It is also one way of strengthening social relations because those without animals can keep and use animals from relatives.

5.3.4 Herd composition

The results of the sex ratio of the cattle and goats herd are presented in Figures 5.2 and 5.3. Cows consisted of 37% compared to bulls 4% of the herd population. The trend was slightly higher for goats with 47% does compared to 5% bucks.. This is because the herdsmen retain female animals for continuity of the herd. Waters-Bayers (1985), Mohammed (1990), Okoruwa *et al*. (1996), Iyayi *et al*. (2003) and Musemwa *et al*. (2007), reported that female cattle usually dominates the herd due to the fact that they are reserved for breeding and milk production with few bulls retained to replace those sold. High proportion of females in the herd also gives the agro-pastoralists a better chance of quickly building up the herd again in the aftermath of disaster such as drought. The high number of oxen in the cattle herd indicated the need of the oxen as a source of draft power for farming and transportation. The breeding ration for cattle was 1 bull per 9.5 cows and for the goats it was 1 buck per 9.5 does. This ratio is within the recommended breeding ratios.

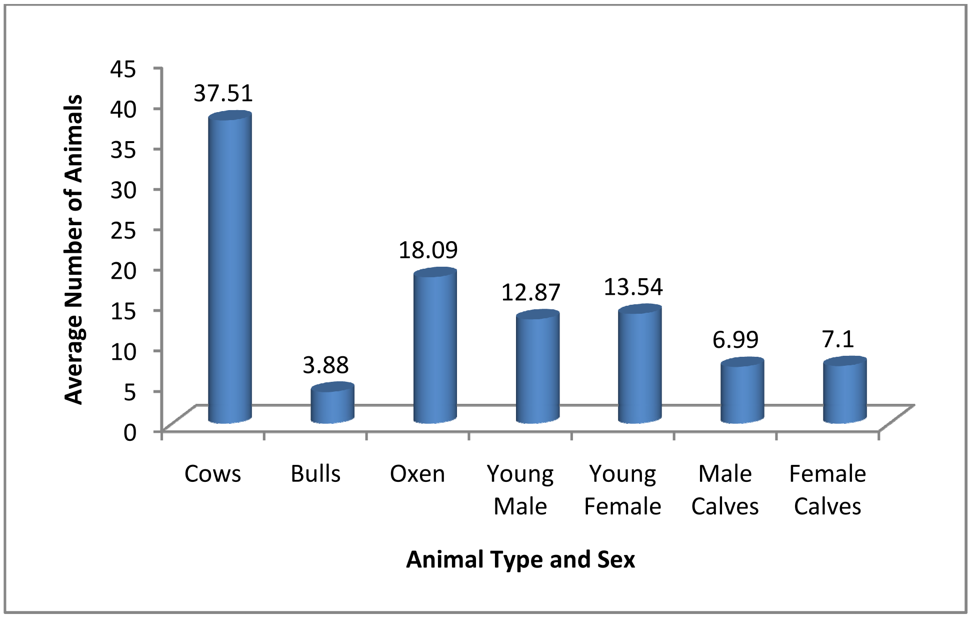


Figure 5.2 Sex Ratio of the Cattle herd

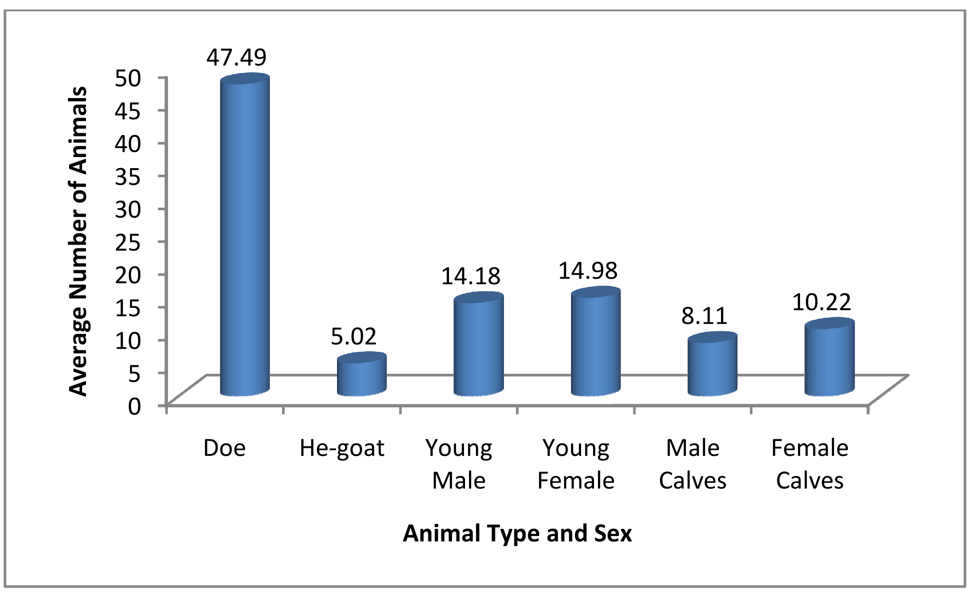


Figure 5.3 Sex Ration of the Goat Herd

5.3.5 Status of the grazing area

The status of the grazing area has been reducing over the years as indicated by 83% of the respondents (Figure 5.4). The reasons for the reduction are due to increase in human population, increase in livestock population and poor management of feed resources in grazing areas. The human population in the district has been increasing at a rate of 1.8% in the past 10 years (CSO 2011). Livestock data also shows that there has been 40% increase in population of cattle and 93% increase of goats over the past decade (CSO 2011). Human population increase has increased the demand of land for settlement and for fields for growing of crops. Population increase cause reduction in grazing lands (FAO 1996). The animals feed resources in grazing areas are further reduced by cutting of trees for charcoal burning and also having uncontrolled fires. The problem of reduced grazing is further compounded by increase in climate variability. With increasing temperatures and increasing frequency of droughts in the area, according to (CEEPA 2006), the moisture available for feed production will be decreasing leading to decrease in livestock production and loss of livelihoods for the people. There is therefore, the need for adaptive feed strategies in the system by identifying and promoting utilization of climate adaptable indigenous forage species.

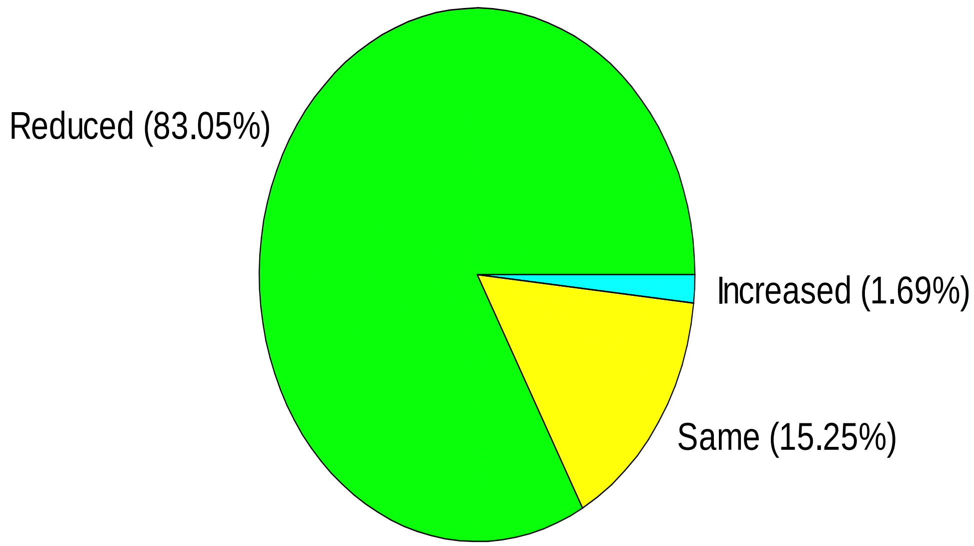


Figure 5.4. Status of the grazing area

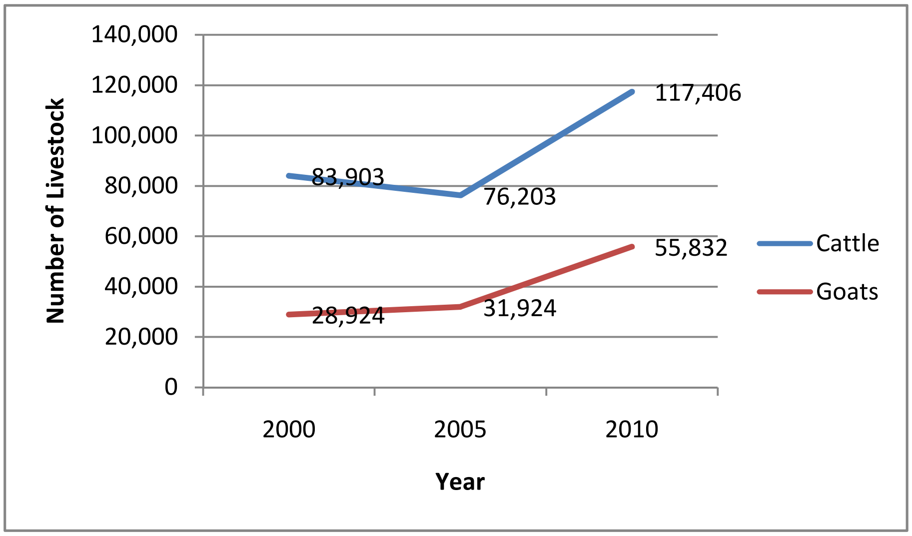


Figure 5.5 Population of cattle and goats in the Choma district over the past decade

5.3.6 Animal feeding strategies during extreme weather conditions

The most important animal feeding strategies during drought included; browse utilization, dambo area grazing, supplementation and upland grazing while during floods upland grazing and browse use were very important (Table 5.1). “Dambo” is a word used for a class of complex shallow wetlands in central, southern and eastern Africa, particularly in Zambia. Daodu *et al.*(2009) also found out that during the dry season important feed sources for animals were from around brooks, dams, rivers and streams. Even during normal weather conditions supplementation during the dry season is still very low among the farmers 8.33% in goats and 48.33% in cattle. Supplementation is by use of, crop residues such as maize and groundnut stover, velvet beans and maize bran. A large number of farmers do not practice feed conservation (65.00%) and 50.00% do not practice pasture management. The farmers indicated that they lacked knowledge on how to conserve and manage pastures while others indicated that they lacked labour. Browse utilization is very important both during drought and floods.

Table 5.1. Animal Feeding Strategies during Extreme Weather Conditions

Feeding Strategy	During Drought % Respondents	During Flood % Respondents
Dambo Grazing	67.80	-
Browse Utilisation	76.78	69.49
Supplementary feeding	8.47	-
Upland Grazing	22.03	77.97
Grazing along streams	18.64	-

5.3.7 Water source

The most important sources of water for livestock use is from streams as indicated by 98.31% of the respondents while water from boreholes and wells are the most important for home use, Table 5.2. The dependence of streams as main water source for livestock makes them to be very vulnerable in times of drought because most of the streams do run dry. However the fact that there is a good number of boreholes in the area means that animals could still survive during drought because they can also use water from the boreholes as long as they do not dry up. Distance to the water supply for livestock is within one kilometer for 50% of the households. The distance to water supply could increase in times of drought as a number of steams could easily dry up. Some pastoralists indicated that during drought animals could cover up to 10 kilometers in search of water. It would be important to consider building a dams in the area since there are no dams.

Table 5.2 Type of Water Source and Distance to Water Source for Home and Animal use

Type of Water Source	Home Use	For Animal Use	Distance to Water Source	Home Use	For Animal Use
Borehole	50.84 %	0 %	less than 500 m	23.73 %	10.17 %
Stream	16.94 %	98.31 %	500-1000m	71.19 %	40.68 %
Well	32.2 %	1.69 %	1100-2000m	5.08 %	45.76 %
			more than 2000m	0 %	3.39 %

5.3.8 Establishment and management of browse trees

Very few farmers (6.78%) know how to establish browse trees and 67.79 % do not carry out any management on them (Figure 5.6). These figures are lower than what Ansah and Nagbila (2011) who found that 66.25% of farmers were establishing browse trees in Ghana. Small holder farmers lack knowledge on establishment, conservation, and utilization of browse (Mupangwa 1994, Mapiye *et al.* 2006). Establishment of effective training-research-extension-farmer and stakeholder linkages can alleviate this problem (Mapiye *et al.* 2006). It is therefore important these farmers are taught how to establish and manage these trees so that they will not be depleted. A number of browse trees have been identified by the farmers as being important as a source of feed for their animals, Table 5.3. These trees have other important ecosystem services such as food, fiber, fuel, building materials, medicines, soil erosion control, biodiversity, nutrient cycling, carbon sinks among others. They should be managed sustainably for continued supply of these services.

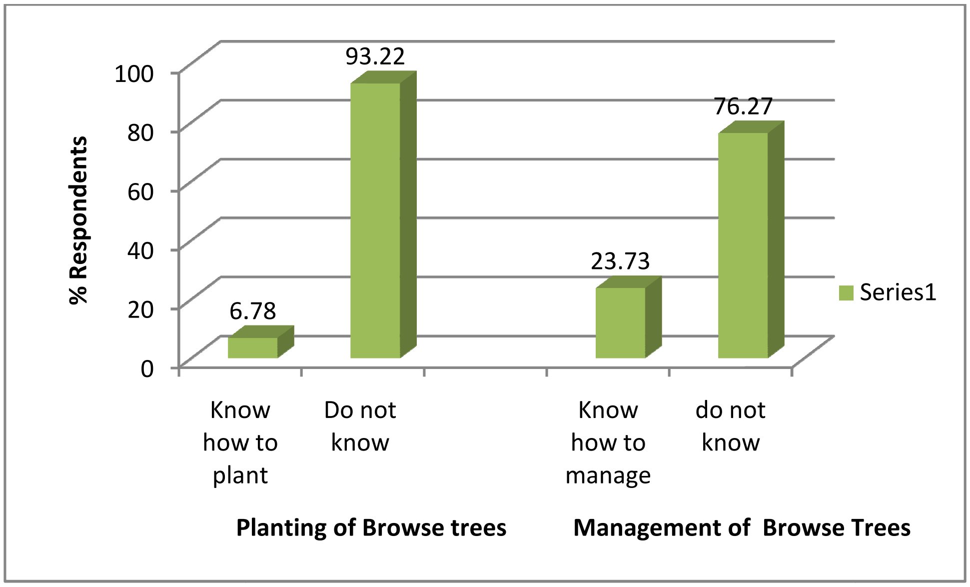


Figure 5.6Planting and management of browse trees

5.3.9 Adaptive use of browse in extreme weather conditions

Browse species are especially important in providing fodder during the dry season (Reddy 2006, Mtengeti 2006, Mogotsi*et al.* 2011) and during drought. In Zambia browse use is critical during the six month dry season from June to November. With increased occurrences of droughts the dependence on browse is going to increase. The agro-pastoralists indicated that in times of extreme weather conditions they depend on climate adaptable browse species such as *Dichrostachys cinerea*(Plate 5.1), *Julbernadia globiflora* (Plate 5.2) and *Piliostigma thinningii* (Plate 5.3)among others, while during floods *Dichrostachys cinerea* and *Piliostigma thinningii were* more popular(Table 5.4). More emphasis should be put on coming up with strategies on how to use these highly ranked species more efficiently. Management practices that could improve their utilization include lopping, coppicing, pruning and pollarding. Planting of these species should also be encouraged so that they are not depleted since some of them have uses such as for timber and making charcoal. One browse tree, *Parinari curatellifolia* (Plate 5.6) was identified as important source of early warning information concerning drought in that is has a tendency to bear excessively in years preceding drought. This is an important climate indicator. This is in line with Roncoli *et al.*(2002) who reported that local climate indicator involve the use of a combination of tree flower production, duration and intensity of cold and hot periods, bird and insect behaviour, and movement of stars and moon to predict precipitation. This indigenous knowledge should be further studied in order to determine its reliability.

Table 5.3. Important browse species used for feeding livestock in Choma district

No.	Local Name	Scientific Name	Parts utilized by animals	Other uses
1	**Mweeye**	*Dichrostachys cinerea*	Leaves, pods	Poles, firewood, medicine, live fence, nitrogen fixing in soil
2	**Muumba**	*Julbernadia globiflora*	New flush of leaves	Firewood, fibre, poles building materials, charcoal, crafts
3	**Musekese**	*Piliostigma thonningii*	Pods, shoots,	Fibre, fire wood, curvings, traditional medicine
4	**Musiwe**	*Brachystegia spiciformis*	Leaves	Fibre, firewood, poles
5	**Mubula**	*Parinari curatellifolia*	Leaves, Fruit	Food, curvings, medicine, charcoal
6	**Muyongolo**	*Swartzia madagascariensi s*	Pods	Curving, insecticides, fish poison, medicine, bee forage
7	**Mubombo**	*Brachystegia boechmi*	Leaves, pods	Fibre, firewood, charcoal, poles
8	**Muunga/ musangu**	*Falbedia albida*	Ripe pods, beans, leaves	firewood, traditional medicine, indicator of soil fertility, flavouring pods
9	**Mango**	*Mangifera indica*	Leaves, fruit	Firewood, traditional medicine
10	**Nakabombwe**	*Combretum molle*	Young leaves	Firewood, timber , medicine
11	**Muyusa**	*Bridelia micrantha*	Leaves	Curvings, medicine
12	**Mucecete**	*Ziziphus mauritiana*	Leaves, fruit	Firewood, charcoal, timber, food, bee forage
13	**Mukuyu**	*Ficus sur*	Fruits	Food
14	**Muntuntumba**	*Terminalia spp*	Leaves	Medicine
15	**Muwi**	*Strychnos spinosa*	Leaves, fruit	Fruit for human food, firewood, timber, medicine, musical instrument
16	**Chiwehehe**	*Capparis tomentosa*	Leaves	Firewood,
17	**Munego**	*Dombeya rotundifolia*	Leaves	Food, wood, curvings
18	**Mulbery**	*Morus alba*	Leaves	Food
19	**Mukunka**	*Psuedolachostyli s maprouneifolia*	Leaves, fruits	Food, fibers, medicine, gum, resin, dye
20	**Mubbiti**	*Crotan guboga*	Leaves	Firewood
21	**Musuku**	*Uapaca kirkiana*	Fruit	Fruit, firewood. Timber

Table 5.4 Farmers response to browse species importance in extreme weather conditions

No	Local Name	Scientific Name	Respondents(%		
			Normal Situation	During Drought	During Floods
1	**Mweeye**	*Dichrostachys cinerea*	90.00	81.67	71.67
2	**Muumba**	*Julbernadia globiflora*	81.67	68.33	3.33
3	**Musekese**	*Piliostigma thonningii*	68.33	46.67	18.33
4	**Musiwe**	*Brachystegia spiciformis*	50.00	48.33	-
5	**Mubula**	*Parinari curatellifolia*	45.00	31.67	8.33
6	**Muyongolo**	*Swartzia madagascariensis*	33.33	23.33	-
7	**Mubombo**	*Brachystegia boechmi*	25.00	26.67	-
8	**Muunga**	*Falbedia albida*	23.33	18.33	3.33
9	**Mango**	*Mangifera indica*	13.33	-	-
10	**Nakabombwe**	*Combretum molle*	11.67	10.00	6.67
11	**Muyusa**	*Bridelia micrantha*	11.67	11.67	-
12	**Mucecete**	*Ziziphus mauritiana*	11.67	8.33	1.67
13	**Mukuyu**	*Ficus sur*	11.67	-	-
14	**Muntuntumba**	*Terminalia*	8.33	6.67	-
15	**Muwi**	*Strychnos cocculoides*	6.67	3.33	-
16	**Chiwehehe**	*Capparis tomentosa*	1.67	1.67	-
17	**Munego**	*Dombeya rotundifolia*	1.67	-	-
18	**Mulbery**	*Morus alba*	5.01	3.39	-
19	**Mukunka**	*Psuedolachostylis maprouneifolia*	1.69	1.69	1.69
20	**Mubbiti**	*Crotan guboga*	1.69	1.69	-
21	**Musuku**	*Uapaca kirkiana*	1.69	-	-

Plate5.7 Some important browse tree species in Choma district.

Plate 5.1
*Dichrostachys cinerea*locally known as Mweeye is a semi-deciduous to deciduous browse tree. It is important for fodder(immature twigs, leaves, pods when they fall to the ground), Poles, firewood, medicine, live fence, nitrogen fixing in soil.
Source; Author.

Plate 5.2 *Julbernadia globiflora*locally known as Muumba is important as a source of browse (from new flush of leaves),firewood, fibre, poles building materials, charcoal, crafts. Source; Author.

Plate 5.3 *Piliostigma thonningii* locally known as Musekese is a shrubby tree which is used for browse (pods and shoots). It is also used for firewood, charcoal, timber, poles, bee- forage, medicine, ropes from its bark, ornamental, tannin, dye (from seed, pods, roots and bark). Source; Author.

Plate 5.4 *Uapaca kirkiana* locally known as Musuku is used for firewood, charcoal, timber, food(fruit is highly valued and sold in local markets), bee forage medicine (roots, bark, leaves) shade and fodder. Fruits can contribute to animal feed. The flush of leaves at the end of the dry season is utilized by cattle as fodder in the absence of more palatable alternatives.Source; Author.

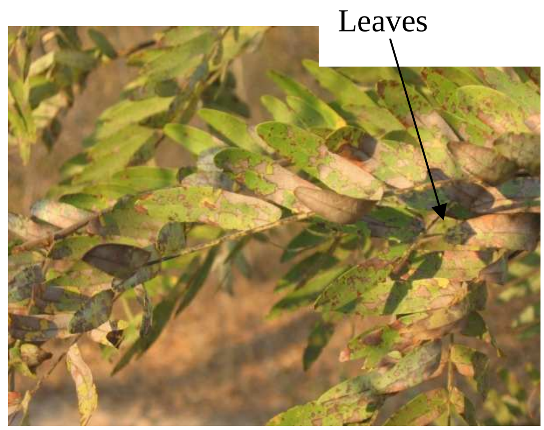


Plate 5.5 *Brachystegia boechmi*locally known as Mobombois important for browse (leaves and pods), fibre, firewood, charcoal, poles. Source; Author.

Plate 5.6 *Parinari curatellifolia* locally known as Mubula. It is important as a source of browse(leaves and fruit). Fruit is highly valued and sold in local markets. The tree is also used for firewood, charcoal, timber and medicine. It is also an important source of early warning information concerning drought in that is has a tendency to bear excessively in each year preceding drought. Source; Author.

5.4 Conclusion.

From this study, the conclusions are that; climate variability is affecting agro-pastoralists in the way they feed their animals and how they are using the feed resources. The people have adaptive strategies of feeding their animals but the adaptive capacity of these strategies are not fully developed hence the need to see how they can be enhanced. However indigenous browse utilisation and upland grazing stand out as the most important livestock feeding adaptive strategies used by the agro-pastoralists in extreme weather conditions. Increasing temperatures may require the livestock keepers to adopt more drought tolerant browse species. The agro-pastoralists know the most important browse species which can be used in extreme weather conditions. Of the identified climate adaptable browse species *Julbernadia globiflora* can preferably be used in enhancing silvo-pastoralism among these agro-pastoralists because it coppices well and could produce reasonably high dry matter yield of browse, hence the need to further investigate it in this area.

5.5 Recommendations

The recommendations from this study were that; goat keeping should be promoted over cattle keeping with increasing climate variability. The agro-pastoralists should be taught how to produce, harvest and conserve various livestock feed resources for improved animal production. There should be replanting of climate adaptable indigenous browse species to increase livestock productivity and enhance food security. On the other hand this will help in reforestation of the drylands and bring stability in the ecosystem.

CHAPTER SIX

EFFECT OF COPPICING OF *JULBERNARDIA GLOBIFLORA*TO DETERMINE THE APPROPRIATE BROWSE HARVESTING REGIME

Abstract

Coppicing is a management practice that can increase the amount of fodder harvested from the trees. The idea is to cut away branches for fodder and wood and allow the tree to regenerate to produce more of the desired product. This study looks at the effect of coppicing a local important drought tolerant browse tree Julbernardia globiflora. A completely randomized block design with three treatments applied. The treatments were 25 percent, 50 percent and 75 percent, removal of the branches. The treatments were repeated three times. After one year measurements on number of shoots and amount of shoot re-growth was done. A survey was also conducted to determine the effect of the intensity of harvesting of Julbernardia globiflora by agro-pastoralists on its regeneration. The cutting height, tree diameter and number of shoot sprouting were measured on trees from 5 sites. Ten trees were measured from each site. Analyses of variance were performed on number shoots and the amount of shoot re-growth accumulated on each tree. Means were compared using significant differences at 5 percent level.

Trees subjected to lower coppicing (25%) had significantly more number of new shoots (69) compared to 11 shoots at 50% coppicing and 9 shoots at 75% coppicing ($P<0.05$). The dry matter yield also followed the same pattern of with low yield recorded as the severity of coppicing increased. The dry matter yield of 586.00

grams at 25% coppicing was significantly higher than all the other levels ($P<0.05$). The survey indicated that more than 80% of the trees were cut within a height of 100cm while less than 2% were cut at a height above 150cm. There was a positive correlation ($R^2 = 0.45$) between the cutting height and the number of shoots that sprouted that was statistically significant ($P<0.05$). These results suggest that browse trees should not be cut close to the ground (< 20cm) so as to balance between the requirement of the local people for wood for various uses, the ease of regeneration of the tree on a sustainable basis and the need of animals to easily reach the tree for dry season browse. It is apparent that coppicing at 25% of the shoots has most positive impact on tree regeneration hence, the most appropriate level of utilisation for the browse in question.

6.1 Introduction

In most semi-arid communal areas browse plays a critical role as livestock feed in the dry season (Sibande 1986, Magadzire 2002, Ndathi 2011). Dry season feed resources are the major factor affecting long term livestock numbers in semi-arid regions. Livestock nutrition is the major constraint to sustainable livestock production in drylands especially during the dry seasons (Mnene *et al.* 2004 and Kibet *et al.* 2006). This is because the natural grasses which form the bulk of the feed resource dry up and lose their high nutritive value and digestibility leading to poor animal performance. Browse trees on the other hand remain green, have higher nutritive value and are still very palatable during the dry season. The leaves, pods and fruits from deciduous browse trees and shrubs are consumed from trees or after they have fallen naturally to the ground (Aregawi *et al.* 2008). Herdsmen can facilitate improved accessibility of leaves, pods and other edible portion of the browse species to livestock during the dry season using sticks or stones or by shaking the browse plants/branches or lopping their branches (Aregawi *et al.* 2008).

Management practices of browse trees include lopping, coppicing, pruning and pollarding. This can increase the amount of fodder harvested from the trees. The idea is to cut away branches for fodder and firewood and to improve the potential of the tree to produce more of the desired produce.

Coppicing is the practice of cutting back a tree to stimulate it to produce new shoots. This method is ideal for producing forage where livestock are not browsing on the tree directly. Coppicing will enhance a bushy regrowth to produce many branches for fodder (Chileshe and Kitalyi 2009). This practice can help to improve the amount of browse during the dry season or extreme weather conditions because the browse trees can regenerate after coppicing. However, Primefacts (2009) suggests that no more than about 60% of tree/shrub foliage be removed and that some tree/shrubs remain unlopped to avoid permanent damage to the trees. *Julbernardia globiflora* coppices well, but trees cut close to the ground (<5cm) produce less coppice growth than plants cut at 1.3 m height (Jimu 2010). In Zimbabwe lopping of branches is carried out in the late dry season to make browse accessible to livestock. However, very little is known about the effect of coppicing on indigenous browse tree species in Zambia. This study therefore examined the effect of coppicing *Julbernardia globiflora* an important indigenous browse tree.

Julbernardia globiflora is a tropical African tree. It is well branched, deciduous, rounded tree, growing to 15m in height. It occurs in mixed deciduous miombo woodland, growing over large areas of the escarpment and the Tonga plateau in Zambia (Chileshe and Kitalyi 2002). It usually occurs at 250-2000m altitude with an average annual rainfall below 1000 mm. It is often dorminant or co-dominant in dry miombo woodland usually occurring with *Brachystegia sperciformis*. The climate in the *Brachystegia-Julbernardia (*miombo) woodland region of southern Africa is characterised by a long dry season (7-8 months) during which herbaceous vegetation dries out and the litter of deciduous woody plants accumulate on the ground (Chidumayo 1991).*Julbernardia globiflora* displays a bright red foliage in late August and then the red colour fades back to green in October/November at the end of the dry season. It has tender leaves which are good fodder for livestock and is important as an early dry season browse plant. The tree has enormous ethno-botanic value in Zambia. It is a bee forage, yielding honey of very high quality and an important food plant for edible caterpillars. Wood is used for poles, tool handles, mortars, yokes harnesses and canoes. It is also widely used for fuelwood and charcoal. The bark yields tannin which is used for dyeing. In Zimbabwe farmers gather *Julbernardia globiflora* leaf litter from adjacent woodlands to improve soil fertility of their fields; it is sometimes moved to kraals and composited with manure before being applied to fields (Jimu 2010).

6.2 Materials and Methods

A completely randomized block design with three coppicing treatments was used on *Julbernardia globiflora*trees. The treatments were 25 percent, 50 percent and 75 percent removal of the branches. The treatments were repeated three times and were applied in August 2010. After one year, measurements on number of shoots and amount of shoot re-growth was done. For the 25% trees which were already found coppiced were measured. A survey was also conducted in the area to find out how the intensity of harvesting of *Julbernardia globiflora* trees by agro-pastoralists affected its regeneration. Five sites were randomly selected and ten(10) coppiced tress were measured from each site. Coppicing height, tree diameter and number of shoots were measured. Data were analysed using GenStat Discovery Edition 3 software programme. Analyses of variance were performed on number shoots and the amount of shoot re-growth accumulated on each tree. Means were compared using significant differences at 5 percent level.

6.3 Results and Discussion

6.3.1 Coppicing relationships with shoots and dry matter production.

Trees subjected to higher copping had less number of new shoots compared to those which were less severely coppiced. The highest was 69 shoots at 25% coppicing while the highest level of coppicing (75%) yielded only 9 shoots. The high yield of shoots at 25% coppicing is as result of less stress on the trees at lower coppicing. The dry matter yield also followed the same pattern with low yield as the severity of coppicing increased. The dry matter yield of 586.00 grams at 25% coppicing was significantly higher than all the others ($P<0.05$) (Table 6.1). This results is similar to Jimu 2010 who found that *Julbernardia globiflora* coppices well, but trees cut close to the ground (<5cm) produce less coppice growth than plants cut at 1.3 m height.

Though the 25% coppicing produced the highest yield it poses a big challenge with regards to feeding animals because most animals would not reach the shoots at this height of more than 2 meters. However an exception can be made for goats because they are able to climb trees in search of browsable material. For cattle and sheep it would be ideal if the shoots are harvested and fed to the animals. Severe copping (75%) though ideal for easy reach of the browse by the animals and good harvest of timber for human use is not good for tree regeneration as evident from the number of shoot re-growth. There is also the danger that shoots from trees coppiced at this intensity could be burnt by uncontrolled bushfires and further delay or even stop their regeneration.

Table 6.1 Effects of Coppicing on *Julbernardia globiflora*

Parameter	Coppicing		
	25%	50%	75%
Tree Circumference	31.33 ± 1.86	29.33 ± 1.33	31.5 ± 2.29
Number of shoots	^{a}69± 5.49	^{b}11± 0.33	^{b}9 ± 2.65
Yield of Dry matter (g)	^{a}586.00± 29.0	^{ab}457.7 ± 27.10	^{b}355.20 ± 29.2

Row means with different letter superscripts are significantly different at P<0.05

Plate 6.1 Uncoppiced. Source; Author.

Plate 6.2 lower cutting height fewer shoots. Source; Author.

Plate 6.3 higher cutting height more shoots. Source; Author.

6.3.2 On-farm coppiced tree characteristics

The survey showed that more than half of the browse trees (52.94%) were cut at a height between 50 and 100 cm followed by 25.46 % of the browse trees which were cut between 20 and 49 cm(Table 6.2). Less than 2% were cut at a height above 150cm. The highest cutting frequency of the 50 -100cm height could be attributed to requirement of this browse tree for other household uses. The tree has various uses such as timber for building huts, fiber, crafts, firewood and charcoal. This cutting height is also ideal for livestock such as cattle, goats and sheep to easily reach the shoots that sprout after the cutting. Cutting the tree higher than 100cm would therefore reduce the amount of wood that would be available for these important uses though it would increase the amount of shoots for browse. Browse trees with a circumference of 31-40cm (10-13 cm diameter) were cut the most (47.06%) followed by browse trees with a circumference of 20 -30 cm (6.6-9.5 cm diameter) (39.21%). Browse trees with 6-11 shoots were followed by those having with 1-5 shoots. Plates 6.2 and 6.3 shows the relationship between the number of shoots and the cutting height.

Table 6.2. Parameters on Harvesting of *Julbernardia globiflora* in Choma District

Parameter		Percentage of Trees (%) N=51
Cutting Height (cm)		
	Less than 20	1.96
	20-49	25.49
	50-100	52.94
	100-150	17.65
	Above 150	1.96
Tree Circumference (cm)		
	0-19	0
	20-30	39.21
	31-40	47.06
	41-50	7.84
	51-60	5.88
Number of Shoots		
	1-5	31.37
	6-11	54.90
	11-15	7.84
	16-20	5.88

Table 6.3 summarizes regression estimates of effect of tree coppicing height and circumference on the number of shoots that sprout. Coppicing height had a positive correlation and was statistically significant ($P<0.05$) while tree circumference had a negative correlation and was statistically insignificant ($P<0.05$). Figure 6.1 shows the relationship between the number of shoots and the cutting height.

Table 6.3Multiple regression of factors affecting the number of shoots that sprout after coppicing

Model	B	Standard Error	T	P-value
Constant	4.47	1.88	2.38	0.02
Coppicing Height (cm)	0.08	0.01	6.59	0.00*
Tree circumference (cm)	-0.08	0.05	-1.62	0.11

Dependent Variable: Number of shoots. $R^2 = 48.3$ F=22.2 * Significant at P<0.05

The regression equation is:

Number of Shoots = 4.47 + 0.0818 coppicing height - 0.0829 tree circumference

There was a positive correlation (r = 0.67) between the cutting height and the number of shoots that sprouted and was statistically significant (P<0.05). The higher the cutting height the more shoots the trees sprouted. This results is similar to Jimu (2010) who found that *Julbernardia globiflora* coppices well, but trees cut close to the ground (<5cm) produce less coppice growth than plants cut at 1.3 m height. Kumar and Tewari (2000) indicated that not more than two thirds of the crown length should be removed preferably with a gap between successive lopping for better yield and sustainable harvest. This positive correlation between cutting height and number of shoots produced is because if the tree is cut at a lower height, it has more stress as a lot of its material is removed and it is shaded by other trees and therefore will be less competitive for solar radiation. This will cause it to have less number of shoot. If the tree is cut at a higher height, it has less stress since less material is removed and it will be more exposed to more light that will be available for more shoot production. Though coppicing at higher height yielded more shoots, it poses a big challenge with regards to feeding animals because most animals would not reach the shoots at higher heights of more than 2 meters. However an exception can be made for goats because they are able to climb trees in search of browsable material. For cattle and sheep it would be ideal if the shoots are harvested and fed to the animals. Severe coppicing (below 20 cm) though ideal for easy reach of the browse by the animals and good harvest of timber for human use is not good for tree regeneration as seen from the number of shoots. There is also the danger that shoots from trees coppiced at high intensity could be burnt by uncontrolled bushfires and further delay or even stop their regeneration.

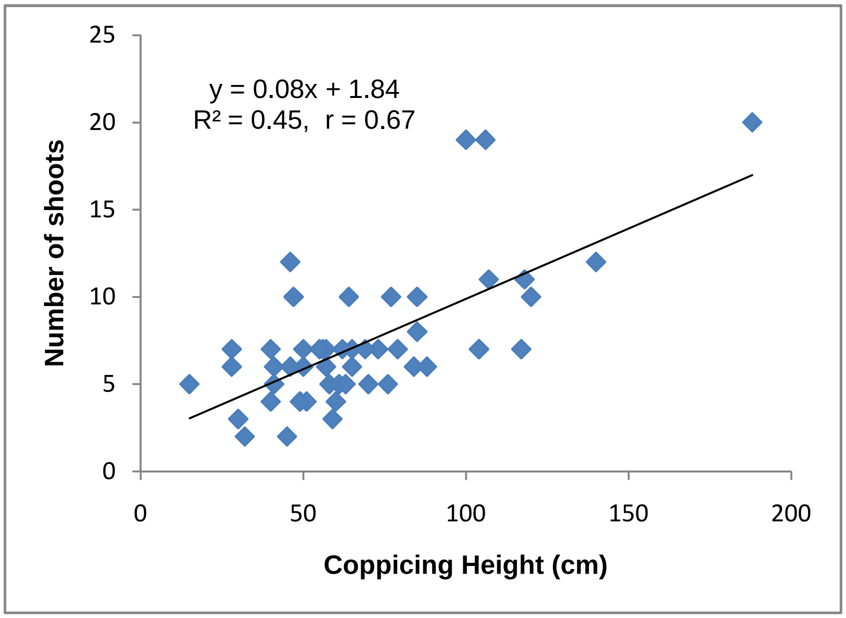


Figure 6.1Relationship between coppicing height and number of shoots of *Julbernardia globiflora*

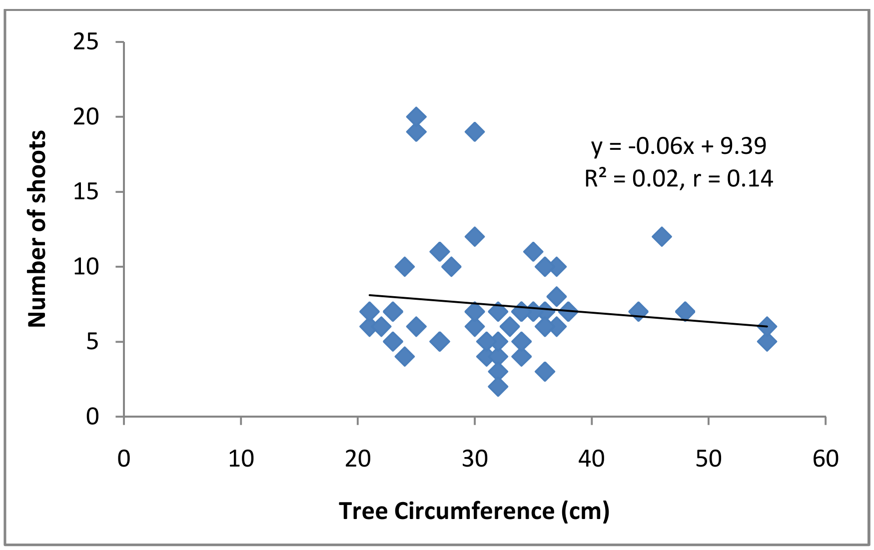


Figure 6.2 Relationship between coppiced tree circumference and number of shoots of *Julbernardia globiflora*

6.4 Conclusion

From this study, the conclusions are that; coppicing *Julbernardia globiflora*at different levels affects the number of shoots and dry matter yield of the shoots. Higher intensity (> 50%) coppicing levels though desirable in order to maximize the amount of produce from the tree reduces the number and yield of shoots for animals to browse. Lower intensity (25%) coppicing levels which produces high number and dry matter yield of shoots reduces the amount of tree produce for use by the farmer and then the produced shoots would not be easily reached by the browsing animals. On farm coppicing showed that more than seventy percent of the browse trees are coppiced above 50 cm which is good for more browse regeneration for livestock feeding. More that 60 percent of browse tree coppice are bigger than 30 cm in circumference which gives a good opportunity for smaller trees to mature before they can be coppiced.

6.5 Recommendations

The recommendations from this study were that; harvesting of *Julbernardia globiflora* should not be cut close to the ground (< 20cm) so as to balance between the requirement of the local people for wood for various uses, the ease of regeneration of the tree on a sustainable basis and the need of animals to easily reach the tree for dry season browse. The best coppicing intensity is around 25%. Other browse species should be studied to determine their best management practices for higher production of browse.

CHAPTER SEVEN

CHEMICAL COMPOSITION AND *IN VITRO*DRY MATTER DIGESTIBILITY OF LEAVES OF *JULBERNARDIA GLOBIFLORA*

(Work published in the Research Journal of Animal Sciences, 6:30-34. Available on http://www.medwelljournals.com/abstract/?doi=rjnasci.2012.30.34).

Abstract

An in vitro dry matter digestibility study of leaves of Julbernardia globiflora at four different post-sprouting stages (early, medium, late and dry) was conducted to determine their usefulness as dry season feed for ruminants. Dried leaf material were used as substrates and analysed for chemical composition and in vitro digestibility. The leaves from the early stage of leaf sprouting had significantly higher levels of crude protein (22.57%), IVDMD (61.04%) and total tannins (6.21), but lower in terms of Crude fibre (16.90%), NDF (32.83%), ADF(12.01%), lignin(8.4%), hemicelluloses(14.01%) and cellulose (10.42%) (P<0.05).Leaves from the dry stage were lowest(P<0.05) in terms of Crude protein (10.29%), IVDMD (38.11%) and total tannins (1.37%), but the highest in terms of NDF (59.83%), ADF(24.72%), lignin(24.32%), and hemicelluloses(17.26%). There was a general decrease in crude protein with increase in maturation of the leaves. There was also a general decrease in total tannins with maturation of the leaves. The amount of tannins in early stage of leaf sprouting (6.21%) differed significantly(P<0.05) to the amount in the late stage (4.14%) and in dry leaves (1.37%) but was similar to the amount in the medium stage (P<0.05).

This study suggests that the leaves of Julbernardia globiflora have high feeding value for ruminants in the dry season. However, use of the leaves in the early stages of leaf sprouting could be limited by high tannin levels.

Key Words: Tannins, sprouting, dry season, maturation, leaves, protein.

7.1 Introduction

In Zambia, as in various parts of the tropics, most small-scale farmers rely on grasses as a major feed source for the grazing animals. However, forage quality (low digestibility and low nutrient content) declines during the dry season. The major factor that limits animal production from these grasses is the fact the animals lose weight due to the nutritional imbalance in the available feed. To mitigate the problem of feed availability, use of browse plants would is as a good option (Haile and Tolemariam, 2008). Use of indigenous browse tress is important because browse species have high persistence in their respective areas (Woodward and Coppock 1995). Herders can rely on fodder trees in the dry season because the foliage retain sufficient crude protein, minerals and energy due to the deep root system of these species (Speedy and Pugliese 1992, Paterson *et al.* 1998; Upreti and Shresta 2006). In Zambia *Julbernardia globiflora* is one of the most important browse species that is utilized by pastoralists in the dry season. New flush of leaves are produced at the beginning of the dry season which are an important source of browse in the dry season. Although leaves of this browse tree are an important source of forage for ruminants during the critical period when quality and quantity of pasture herbages are limited there is little information about the nutritive value of leaves of indigenous browse trees. Leaves at four stages (Figure 5.1) from sprouting namely; early, medium, late and dry stages were analyzed. The early stage is the beginning of the sprouting which occurs mainly in August/September; the medium stage is around October/November when the sprouted leaves are beginning to mature, the late stage is around December when the leaves have fully matured; and the dry stage is June/July when the matured leaves have dried and are dropping on the ground (Table 5.1). Therefore, it is important to evaluate the potential nutritive value of leaves based on their chemical composition, and *in vitro* dry matter digestibility at different sprouting stages.

Plate 7.1 The different sprouting Stages of *Julbernardia globiflora*

Early stage Meduim stage Late stage Dry stage

Source; Author

Table 7.1 Characteristics of different sprouting Stages of *Julbernardia globiflora*

Early stage	Medium stage	Late Stage	Dry Stage
August/September	October/November	December to May	June/July
New flush of leaves. The leaves have a red colour.	Newly sprouted leaves begin to grow and the red colour begin to fade to green	Leaves mature and they completely become green in colour	Mature leaves dry up and drop on the ground. They are locally known as 'Nkwalani'.

Chemical composition can be known by carrying out proximate analysis and parameters such as percentage Dry Matter (DM), Crude Protein (CP), Neutral Detergent Fibre (NDF), Acid detergent Fibre (ADF), and key minerals such as Calcium (Ca) and Phosphorus (P) can be used to measure forage quality. *In vivo* digestibility of many different herbages, have shown that digestibility could be an important index of the relative feeding value of a herbage. However, such measurements are costly when carried out with animals; a technique for the prediction of digestibility by a laboratory method is therefore desirable. Chemical analysis of herbages alone is not adequate for such prediction purposes. The *in vitro* digestion technique is a good laboratory method for estimating the digestibility of herbage. Reid*et al.*(1964) found *invivo* dry matter digestibility was closely related to *in vitro* cellulose digestibility, but anomalies in the relationship have been reported by Quicke *et al.* (1959) and Naga and Shazly (1963).Therefore, *in vitro* digestion is a biological method in which, under conditions which simulated those within the rumen of a ruminant (anaerobic, near neutral pH, blood heat), small samples of herbage could be digested with crude rumen liquor rich in micro-organisms.

This laboratory technique for determining the digestibility of dried forages involves incubation first with rumen liquor and then with acid pepsin solution (Tilley and Terry 1963). The rumen inocula, is capable of dealing with the digestible structural carbohydrates, while the digestible protein could, be readily removed by a second-stage treatment with acid-pepsin. *In vitro* and *in vivo* results are in very close agreement over a very wide range of herbage samples. Methods based on the use of enzymes rather than rumen liquor have subsequently been used. It is therefore important to measure the chemical composition of browse trees and to carry out *in vitro* digestibility studies in order to determine the level usefulness and effectiveness of the browse species as feed for the animals in extreme weather conditions.

7.2 Materials and Method

The samples (leaves) for this study were collected from Choma district in southern Zambia during the 2011 dry season. Leaf samples from the four stages from sprouting namely; early stage, medium late stage and dry stages were collected and then they were dried in the shade. The dried samples were ground to pass through a 2 mm screen and analysed for proximate composition according to (AOAC 1995).

For in vitro dry matter digestibility (IVDMD) analysis, (1g) of each sample was weighed with 0.1 mg accuracy in a stoppered 120ml culture vials bottles. Phosphate buffer (p^H 7.35) (35mL, 0.1M) containing 1% sodium lauryl sulphate, and 1% 2-mercaptoethanol (w/v) was added and the resultant mixture homogenized by gentle stirring. Pronase solution (5mL, 5mg/mL in 0.1M phosphate buffer, p^H 7.35) was added and mixture placed in an oscillating water bath (40^{o}C) for 2 hours. The mixture was rinsed with 15mL distilled water, and the washings were filtered and the proteolysis supernatant was discarded. The residue or pellet from proteolysis was suspended in hot (96.8 ^{o}C) 90% dimethly sulfoxide (10mL) and transferred into a stoppered 120ml culture vials bottles. The mixture was homogenized by gentle stirring, placed in a boiling water bath (96.8 ^{o}C) for 30 minutes. Boiling 0.1M acetate buffer (p^H 5.66, 30mL) was added and the resultant solution mixed thoroughly; 0.5M of Termamyl 60L was added and the resultant solution was mixed and allowed to remain in the boiling water bath for an additional 15 minutes. The Erlenmeyer flask was withdrawn and left on the bench to cool to 40^oC. Aminoglucosidase solution (5mL, 20 mg/mL in 0.1M acetate buffer, p^H 5.66, was added and the flask placed in water bath (40^oC) for 2 hours. The contents were filtered and the amolysis supernatant was discarded. The final residue (pellet) was washed thoroughly with distilled water, re-suspended in 50 mL of absolute ethanol and filtered through a weight fritted glass crucible (porosity 4, o.d. pores 10-16 um). It was dried by acetone and then diethyl oxide (50mL) each placed in a vacuum oven (0.50 psi) overnight at 70 ^oC, cooled in a dessicator and weighted with0.1mg accuracy. Finally, the pellet was incinerated at 550 ^oC for 4 hours and weighed with 0.1 mg accuracy.

$$\text{Insoluble cell walls (\%)} = \frac{\text{weight of residue} - \text{weight of ashes}}{\text{Weight of sample}}$$

The total tannins were determined by the Folin and Ciocalteu method. 100g of dried (finely ground; passed through a 0.5mm screen) of the leaves (100grames) was taken into a glass beaker of approximately 25ml capacity. Five ml of aqueous acetone (70%) was added and subjected to ultrasonic treatment for 20 minutes at room temperature. The contents of the beaker were transferred to centrifuge tubes and subjected to centrifugation for 10 minutes at approximately 3,000 *g*. The supernatant was collected and the pellet left in the centrifuge tube was transferred to the beaker using two portions of 5 ml each of 70% aqueous acetone and again subjected the contents to ultrasonic treatment for 20minutes. The contents were centrifuged for 10 minutes at approximately 3,000 *g*. Then, 0.01ml of aliquots containing tannin were put in tests tubes and the volume was made up to 0.5ml with distilled water. 0.25ml of the Folin-Ciocalteu reagent and 1.25ml of sodium carbonate solution were added. The mixture in the tubes was vortexed and absorbance was read at 725nm after 40 minutes. The total amount of phenols, as tannic acid equivalent were calculated from a calibration curve and the total phenolic content was expressed on dry matter basis.

7.2.1 Data analysis

The data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of Minitab Reference Manual Release 13 (Minitab 2000).

7.3 Results and Discussion

The results for the chemical content of the leaves are shown in Table 7.2. The leaves from the early stage of leaf sprouting had the highest levels of crude protein (22.57%), IVDMD (61.04%) and total tannins (6.21), but lowest in terms of Crude fibre (16.90%), NDF (32.83%), ADF(12.01%), lignin(8.4%), hemicelluloses(14.01%) and cellulose (10.42%). Leaves from the dry stage were lowest in terms of Crude protein (10.29%), IVDMD (38.11%) and total tannins (1.37%), but highest in terms of NDF(59.83%), ADF(24.72%), lignin(24.32%), and hemicelluloses(17.26%).There was a general decrease in crude protein with increase in maturation of the leaves. This is similar to what Khazaal *et al.* (1993) found. This decrease in crude protein as the leaves mature could make nitrogen the limiting factor to intake and digestibility. However the protein range is still above the adequate range (10-13%) for maintenance and growth for cattle, sheep and goats (Kearl 1982). This protein levels compares well and is even better crude protein content (22.57% CP young leaves) than that of *Faldebia albida* (17.1% CP young leaves) which is an important browse specie in North Africa and *Acacia tortilis* (6.46% CP twigs and leaves) an important browse specie in East Africa. Calcium content was within the required levels for ruminant growth while phosphorus content was lower than the ruminant animal requirement. Similar results were obtained by Olsson and Welin (1989) and Bhalahenda (2001). It is therefore important to supplement minerals to browsing animals. The changes in NDF and ADF are the major determinants of forage quality (Van Soest 1994).The NDF content ranged from 32.83% to 59.83% while that of ADF ranged from 12.01% to 24.72% and compared well with those reported by (Romero *et al.*2000; Bhalahenda 2001; Kuria *et al.* 2005; Kamalak 2005).

Table 7.2. Nutritive Value and in-vitro digestibility of four different re-growth stages of *Julbernardia globiflora*

Parameter	**Early**	**Medium**	**Late**	**Dry**
Crude Protein (%)	$22.57^{a} \pm 1.11$	$14.30^{b} \pm 0.10$	$14.09^{b} \pm 0.14$	$10.29^{c} \pm 0.99$
Ether Extract (%)	$1.23^{a} \pm 0.05$	$3.27^{b} \pm 0.05$	$4.94^{c} \pm 0.11$	$1.03^{a} \pm 0.01$
Crude Fiber (%)	$16.90^{a} \pm 1.58$	$23.75^{ab} \pm 2.96$	$32.05^{b} \pm 2.28$	$25.86^{ab} \pm 1.51$
NDF (%)	$32.83^{a} \pm 2.87$	$43.34^{b} \pm 0.13$	$53.4^{c} \pm 0.84$	$59.83^{c} \pm 0.06$
ADF (%)	$12.01^{a} \pm 1.64$	$15.66^{ab} \pm 0.23$	$20.74^{bc} \pm 0.47$	$24.72^{c} \pm 1.54$
Lignin (%)	$8.4^{a} \pm 1.26$	$10.87^{a} \pm 0.20$	$14.42^{a} \pm 2.02$	$24.32^{b} \pm 0.68$
Hemicellulose (%)	14.01 ± 0.55	16.48 ± 0.57	16.81 ± 0.33	17.26 ± 1.29
Cellulose (%)	$10.42^{a} \pm 1.04$	$16.00^{b} \pm 0.08$	$19.68^{b} \pm 1.00$	$18.31^{b} \pm 0.67$
Ash (%)	$4.23^{ab} \pm 0.22$	$4.88^{a} \pm 0.42$	$3.41^{b} \pm 0.06$	$3.20^{b} \pm 0.38$
Calcium (%)	$0.98^{bc} \pm 0.08$	$1.28^{a} \pm 0.03$	$0.93^{c} \pm 0.02$	$1.14^{ab} \pm 0.03$
Phosphorus (%)	$0.52^{a} \pm 0.01$	$0.32^{b} \pm 0.01$	$0.20^{c} \pm 0.01$	$0.28^{b} \pm 0.01$
IVDMD (%)	$61.04^{a} \pm 1.84$	$47.71^{ab} \pm 0.49$	$42.26^{b} \pm 4.86$	$38.11^{b} \pm 0.06$
Tannins	$6.21^{a} \pm 0.09$	$5.06^{ab} \pm 0.25$	$4.14^{b} \pm 0.16$	$1.37^{c} \pm 0.62$

Row means with a different superscript are significantly different ($p<0.05$)

NDF was also negatively correlated with IVDMD(R^2 = -0.96) (Figure 7.1). This is similar to what Solorio-Sanchez *et al.* (2000) found in leaves of fodder trees in South East Mexico. ADF was also negatively correlated with IVDMD(R^2 = - 0.90) (Figure 7.2) while crude protein was positively correlated with IVDMD(R^2 = 0.96) (Figure 7.3).

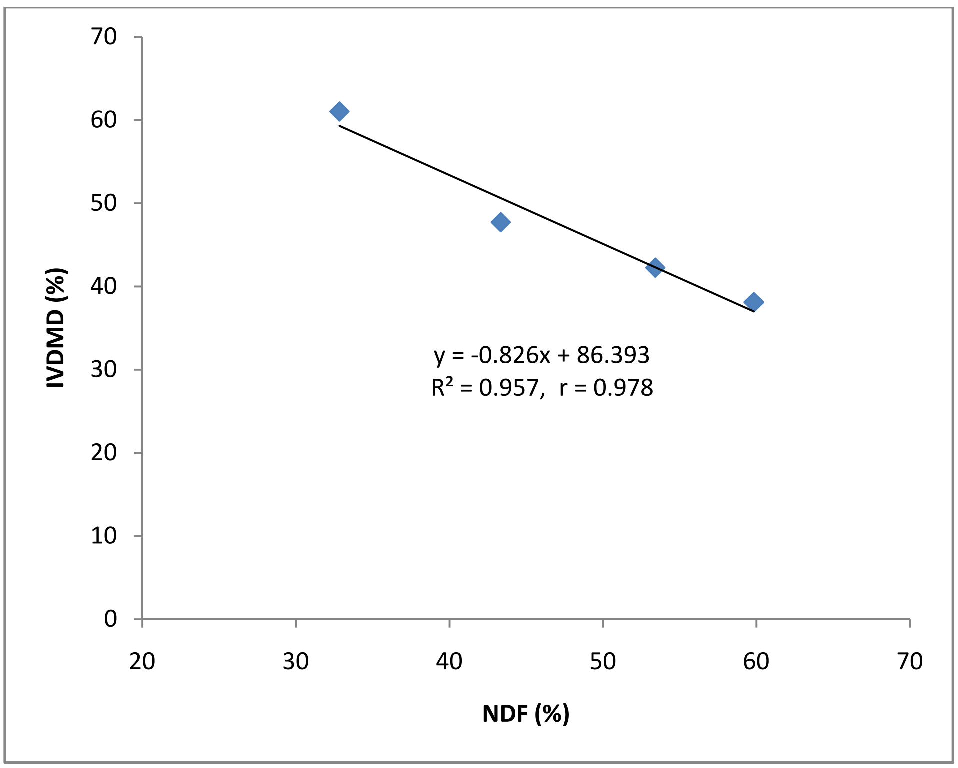


Figure 7.1 Relationship between IVDMD and NDF content of the leaves of *Julbernardia globiflora*

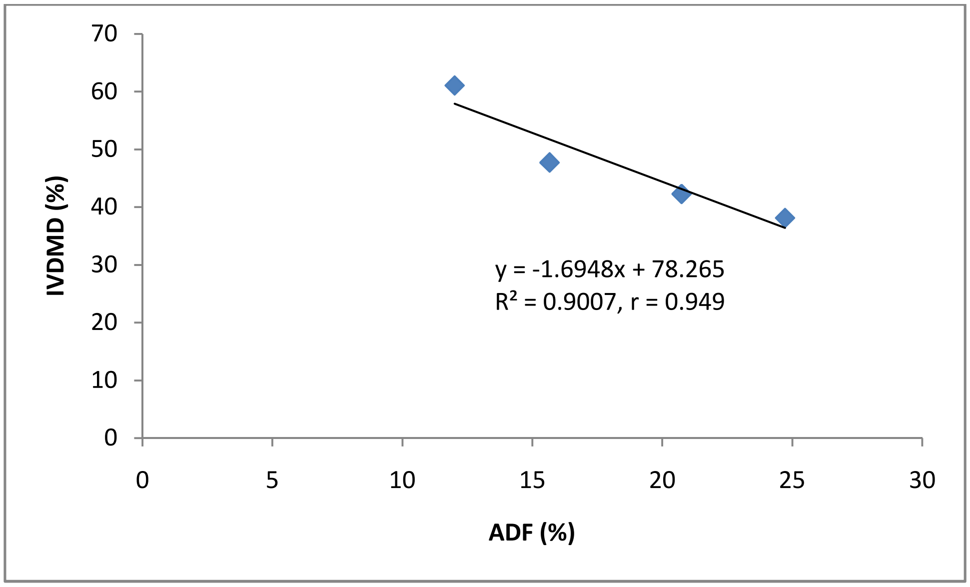


Figure 7.2 Relationship between IVDMD and ADF content of the leaves of *Julbernardia globiflora*

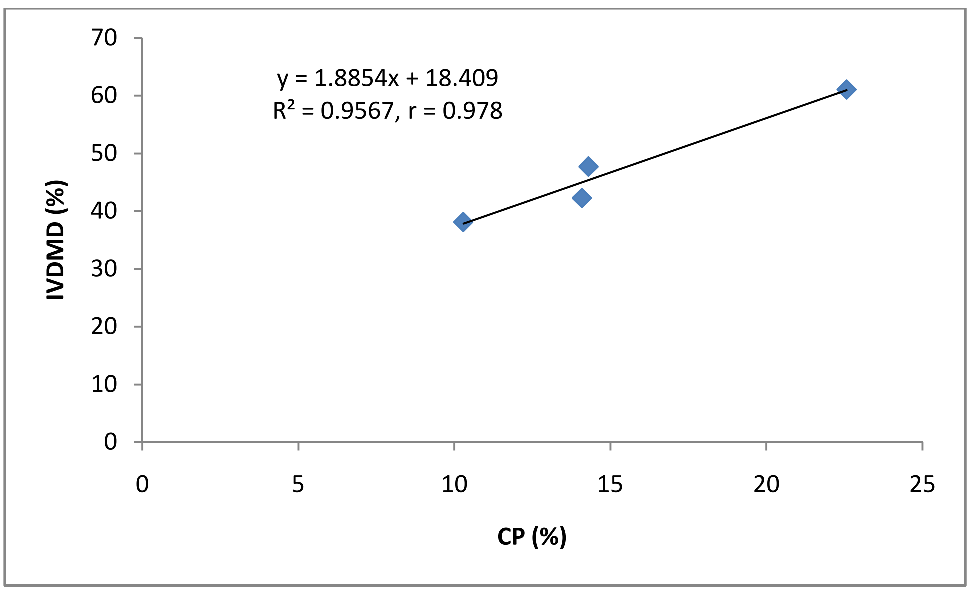


Figure 7.3 Relationship between IVDMD and CP content of the leaves of *Julbernardia globiflora*

There was a general decrease in total tannins with maturation of the leaves. The high amount of tannins in young leaves (6.21%) differed significantly to the amount in mature leaves (1.37%). Koukoura and Nastsi (1992)also found general decrease in total tannins with maturation of the leaves in selected fodder trees in the Mediterranean zone. The red colour of the leaves in early sprouting is probably an indicator of the high tannins levels. These high tannins levels may play an important role in prevention of predation (Forkner *et al.* 2004) and regulation of plant growth (Ferrell and Richard 2006). It has been speculated that tannins are an ecologically developed defense mechanism. Provenza and Malechek (1983) have reported that plant parts that are more succeptible to herbivory damage contain higher tannin concentration than their counterparts which have been developed at heights beyond the animal reach.

Tannins therefore play an important role in affecting forage preference and quality. They can bind both proteins and carbohydrates. Their binding ability varies according to their chemical structure. Tannins bind to proteins and modify the rate and extent of their digestion (Feeny 1970). Feed intake is depressed when feed contains relatively high levels of tannins at least above 5%. The limited intake may result partly from reduced digestion since condensed tannins seem to depress digestion. The leaves in the early stages of sprouting though they contain very high crude protein and high IVDMD and very low crude fibre may not necessarily be consumed in high amount and utilised well by the animals because of the high levels of tannins.

7.4 Conclusion

From this study, the conclusions are that; leaves of *Julbernardia globiflora*have a good potential to supply highly digestible feeds suitable for ruminants in the dry season. The high protein and digestibility levels in the early stages of leaf sprouting provides a good opportunity for use as browse for the animals at a time when grass resources are dwindling in quantity, quality and digestibility. However the high tannin levels could cause a serious limitation to feed intake.

7.5 Recommendations

The recommendations from this study were that; there is need for more research on how to reduce tannin levels to ensure better utilization of the browse material. Also there is need to test feed the browse and measure animal production (growth rate and animal function variables). There is need for continued evaluation and promotion of the use of other important indigenous browse species for improved livestock nutrition during the dry season and drought periods.

CHAPTER EIGHT

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

8.1 General Discussion

8.1.1 Climate variability and livelihood coping strategies

Agro-pastoralists perception of climate variability shows that temperature, the frequency of floods and drought increased over the previous three decades in Southern Zambia. This is supported by climatic data which revealed an increase of 1.0 ^{o}C in the average annual temperatures over the previous six decades. This is slightly higher than the empirical evidence that shows a warming of approximately 0.7^{o}C over most of Africa during the 20th Century (IPCC 2007). IPCC 2007 indicated that a 3 ^{o}C temperature increase could lead to 0.4 to 1.8 billion more people at risk of water stress. The population at risk due to increased water stress in Africa is projected to be between 75-250 million people by 2020 and 350-600 million by 2050. This increase in average temperatures would cause a reduction on water availability which will impact negatively on livelihoods of the people since they depend on rain fed agriculture. Increase in temperature can also cause decrease in livestock productivity directly and indirectly through changes in the availability of feed and fodder. Variability in the total amount of annual rainfall received has increased over the same period while there was a general decline in mean annual rainfall received. This decline of mean rainfall from 869.92 mm of rainfall in the 1950s to 813.59mm in 2010 represents a decline of 6.0 mm of rainfall per decade. This amount is higher than what Hume *et al.* (2001) reported, who found a decrease in precipitation by about 2.4 $\pm$ 1.3 mm per decade in tropical rainforest of Africa since the mid 1970s.Most of the agro-pastoralists are coping with these extreme weather conditions through livestock sales and engaging in non-agricultural activities. Non-agricultural activities include harvest of products from the forest such as charcoal burning, sale of firewood, carpentry, carving and sale of thatching grass. Others engage in trading, working for others, bee keeping, brick-laying, knitting and fishing. This shows how diverse the livelihood strategies can be. This gives further testimony to the diverse livelihood strategies employed by people in semi-arid areas observed by Twyman et al 2004, Dube and Sekhwela 2007 and Mogotsi *et al* 2012. With projected further increase in climate variability, some of these coping strategies will need to be enhanced to ensure continued survival of the agro-pastoralists in these extreme weather conditions. Use of forest resources was a key survival strategy. However, harvesting of forest products has its own challenges in that it leads to deforestation and land degradation. There is need to come up with reforestation programmes to ensure long-term sustainability of this coping strategy. Reforestation with indigenous tree species can provide long term environmental, economical and social benefits. Other coping strategies such as bee keeping should be encouraged because they promote the well-being of the forest ecosystem and does not lead to degradation of grazing areas. Land issues and policies are also key considerations for adaptation planning, which are needed to strengthen land tenure and management arrangements in risk environments, and secure supplies and access arrangements for land for resettlement and changing livelihood demands.

Without effective tenure policies in administering land, sustainable development in these areas will be threatened. To this effect, the issue of boundaries in customary communities should be strengthened to ensure territorial integrity and land management in customary land. The need for cadastral surveys is becoming more apparent with the rise in population and demand for market based activities in rural land because without clearly defined systems of administration and demarcation of boundaries, customary land in Zambia is prone to more land conflicts hindering socio-economic progress.

8.1.2 Livestock feeding strategies in extreme weather conditions

The major livestock feeding strategies during droughts were browse utilization, dambo grazing, grazing along streams and supplementary feeding, while during floods upland grazing and browse grazing were the main strategies. In most semi-arid communal areas browse plays a critical role as livestock feed in the dry season (Sibanda 1986, Magadzire 2002, Ndathi 2012). To improve the quality of feed given to animals use of locally adapted green fodder legumes and browse trees have been recommended in many parts of the tropics (Simbaya 2002). Browse utilisation will continue to be an important feed resource for the grazing animal because it is less affected by climate variability compared to grasses. Twenty one (21) tree browse species were important for livestock feeding in Southern Zambia and of these (17) species were important during droughts and eight (8) during floods. The top five ranked browse species during droughts were *Dichrostachys cinera,Julbernadia globiflora, Piliostigma thonningii, Brachystegia spiciformis and Parinari* *curatellifolia.* More research should be targeted towards better management and utilisation of these browse species for feeding livestock. This will avoid disappearance of some browse species through over-utilisation. The indigenous knowledge systems and use need to be strengthened to enhance their multiple uses such as firewood, traditional medicine, insecticides, timber, charcoal and making musical instruments, among others. Also deliberate effort should be made to teach the agro- pastoralists how to plant and manage these important browse species that are suitable in extreme weather conditions. Browse trees on the other hand remain green, have higher nutritive value and are still very palatable during the dry season. The leaves, pods and fruits from deciduous browse trees and shrubs are consumed from trees or after they have fallen naturally to the ground (Aregawi *et al*. 2008). Herdsmen can facilitate improved accessibility of leaves, pods and other edible portion of the browse species to livestock during the dry season using sticks or stones or by shaking the browse plants/branches or lopping their branches (Aregawi *et al.* 2008). Integrating browse trees, forage and livestock creates a land management system to produce marketable products while maintaining long-term productivity. This will enhance productive use of the browse species for improved animal feeding to ensure food security among the pastoralists.

8.1.3 Coppicing of Julbernadia globiflora

One important browse management practice found to be useful in the area is coppicing. Coppicing *Julbernadia globiflora increases* the amount of fodder from the trees as the trees produced new fodder re-growth after harvesting. It also contributes to production of other tree products such as timber. However, ideal harvesting should not be cutting too close to the ground (< 20cm). Kumar and Tewari (2000) indicated that not more than two thirds of the crown length should be removed preferably with a gap between successive lopping for better yield and sustainable harvest. Jimu (2010), indicates that some browse species such as *Julbernardia globiflora* coppices well, but trees cut close to the ground (<5cm) produce less coppice growth than plants cut at 1.3 m height. This is in agreement as the results in this study showed that more shoots were produced from trees that were cut much higher. It is also apparent that coppicing intensity > 25% tends to depress tree regeneration. There is need to ensure a balance between the ease of regeneration of the tree on a sustainable basis, the need of animals to easily reach the tree for dry season browse and the requirement of the local people for wood for various uses. The other browse species should be studied to determine their best management practices for higher forage output.

8.1.4 Nutritional properties of leaves of *Julbernadia globiflora*

Forage trees and shrubs must have nutritive value to be useful as forage. The nutritive value of trees and shrubs forage is determined by its ability to provide the nutrient required by an animal to balance requirements (Berg 2010).Herders can rely on fodder trees in the dry season because the foliage retain sufficient crude protein, minerals and energy due to the deep root system of these species (Speedy and Pugliese 1992, Paterson *et al.* 1998; Upreti and Shresta 2006). In Zambia *Julbernardia globiflora* is one of the most important browse species that is utilized by pastoralists in the dry season. Nutritional analysis of leaves of *Julbernadia globiflora* showed that they have high feeding value for ruminants in the dry season. The protein range of the leaves was above the adequate range (10-13%) for maintenance and growth for cattle, sheep and goats (Kearl 1982). It compares well with other browse trees elsewhere. It has even better crude protein content (22.57% CP young leaves) than that of *Faldebia albida*(17.1% CP young leaves) which is an important browse specie in North Africa and *Acacia tortilis*(6.46% CP twigs and leaves) an important browse specie in East Africa. However, use of the leaves of *Julbernadia globiflora*in the early stages of leaf sprouting could be limited by high tannin levels. These high tannins levels may play an important role in prevention of predation (Forkner *et al.* 2004) and regulation of plant growth (Ferrell and Richard 2006). It has been speculated that tannins are an ecologically developed defense mechanism. Provenza and Malechek (1983) have reported that plant parts that are more succeptible to herbivory damage contain higher tannin concentration than their counterparts which have been developed at heights beyond the animal reach. Tannins bind to proteins and modify the rate and extent of their digestion (Feeny 1970). Feed intake is depressed when feed contains relatively high levels of tannins at least above 5%. The limited intake may result partly from reduced digestion since condensed tannins seem to depress digestion.The recommendations from this study were that; there is need for more research on how to reduce tannin levels to ensure better utilization of the browse material. Also there is need for continued evaluation and promotion of the use of other important indigenous browse species for improved livestock nutrition during the dry season and drought periods. This will call for practical methods such as feeding and production studies supported by more intensive laboratory evaluations.

8.2 Conclusion

From this study, the following were the key conclusions, that;

- There has been an increase in climate variability over the last five decades in Southern Zambia.
- Farmers have the right perceptions concerning climate variability and extreme weather conditions and is seen in the way the carry out their farming activities and adaptation to the extreme conditions. Livestock sales and use of forestry resources are the key coping and adaptive strategies to climate variability in the study area.
- Indigenous browse utilisation is the most important livestock feeding adaptive strategy used in extreme weather conditions. Agro-pastoralists know the most important browse species which can be used in extreme weather conditions.
- Browse management practices such as coppicing at different levels affects the number of shoots and dry matter yield of the shoots. Coppicing of one important browse species *Julbernardia globiflora* showed that higher coppicing levels though desirable in order to maximize the amount of forage from the tree reduces the number and yield of shoots for animals to browse. Lower intensity coppicing levels produces high number and dry matter yield of shoots but reduces the amount of tree produce for other uses by the farmer. It also produces shoots that could not be easily reached by the browsing animals. On farm coppicing showed that more than seventy percent of the

browse trees are coppiced above 50 cm which enhances high browse regeneration for livestock feeding.

- Nutritional analysis revealed that leaves of *Julbernardia globiflora*have a good potential to supply highly digestible feeds suitable for ruminants in the dry season. The high protein and digestibility levels in the early stages of leaf sprouting provides a good opportunity for use as browse for the animals at a time when grass resources are dwindling in quantity, quality and digestibility. However the high tannin levels could cause a serious limitation to feed intake.

8.3 Key Recommendations

The following are the key recommendation from this study, that:

- There is need to encourage alternative livelihood strategies to climate variability so as to reduce the potential negative impact of excessive exploitation of forest and forest products particularly deforestation and associated land degradation. This will ensure sustainable utilization of the natural resources for the long term benefit of the Agro-pastoralists.
- There are challenges associated with some of the alternative strategies for example charcoal burning which leads to deforestation should be mitigated by promotion of national reforestation programmes.
- Land issues and policies are key considerations for adaptation planning, which will need to strengthen land tenure and management arrangements in these risk environments, and secure supplies and access arrangements for land for resettlement and changing livelihood demands.
- Agro-pastoralists should be taught how to produce, manage, harvest and conserve various livestock feed resources for improved animal production.
- There should be replanting of climate adaptable indigenous browse species to increase livestock productivity and enhance food security. On the other hand this will help in reforestation of the drylands and bring stability in the ecosystem.
- Browse management practices such as coppicing should be encouraged in Southern Zambia while ensuring that there is a balance between the ease of regeneration of the tree on a sustainable basis, the need of animals to easily

reach the tree for dry season browse and the requirement of the local people for wood for various uses.

- There is need for more research on how to reduce tannin levels to ensure better utilization of browse in livestock feeding
- There is need for continued evaluation and promotion of the use of other important indigenous browse species for improved livestock nutrition during the dry season and drought periods.

8.4 Further Research

From the study, the following areas were identified as requiring further research;

1. Evaluation of adaptation strategies and the costs of adaptation at local and national level.
2. Development of cheap feed conservation strategies for improved feed availability in extreme weather conditions.
3. Evaluation of different management practices on other indigenous browse species to determine their best production levels.
4. Evaluation of different methods that can be used to reduce tannins levels to ensure better utilisation browse in livestock feed.
5. Evaluation of types of tannins in the different indigenous browse species and their effects on feed palatability and nutrient availability.

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APPENDICES

Appendix 1: questionnaire survey on climate variability and livelihood strategies and livestock management.

Respondent number……………….........….
Village...

Section A

Socio Information

1. Age ………………………………………
2. Number of children…………Boys……………………Girls………………
3. Number of wives…………….
4. Level of education……………………………………………………
5. Main agricultural activities..

   ....
6. Other agricultural activities...

   ....

   ....

   ....
7. Has climate changed in the past 30-40 years

   Yes.. No.......................................

8. If yes above, in what way has climate changed?

   ☐Increase in rainfall amount ☐ Reduction in rainfall amount

   ☐ Late onset of rains ☐ Hotter weather

   ☐ Colder weather

9. What type of climate variability have you experienced?

☐ Only drought increased ☐ Only drought reduced

☐ Both floods and droughts increased

☐ Both floods and droughts reduced

☐ Only floods increased ☐ Only floods reduced

☐ No change ☐ Not sure

10. Means of Livelihood and Sources of Income

Means of livelihood	**Normal situation**	**Most important during periods of drought**	**Most important during periods of floods**
Livestock Crops **Off farm employment** Trade Working for others **Sources of income** Sale of animals Sale of animal products Sale of crops Others			

11. Main source of income……………………………………………………….

12. Other sources of income………………………………………………………

…………………………………………………………………………..............

…………………………………………………………………………..............

…………………………………………………………………………..............

13. Types of crops grown………………………………………………………

…………………………………………………………………………..............

…………………………………………………………………………..............

Livestock management

14. Types of livestock kept

Type of Livestock	Breeding		Weaners		Suckling		Total
	Male	Female	Male	Female	Male	Female	
Cattle Goats Sheep Donkeys Chickens Other							

NB For cattle number of oxen should be taken……………………………………

15, Purposes of keeping cattle and their ranking order according to importance

Purpose	**(n =60)**	
	Respondents, %	**Ranking order**
Socio-Economic uses		
Home consumed milk		
Home consumed meat		
Store of wealth /assets		
Income from livestock products and live animals sales		
Security (savings and insurance)		
Draught power		
Manure		
Socio-cultural uses		
Dowry payments		
Prestige		
Sacrifice		
Hides/skin		
others		

16. Cattle ownership.

- ☐ Husband only
- ☐ Wife only
- ☐ Children only
- ☐ Husband and wife only
- ☐ Husband, wife and children
- ☐ Relatives only
- ☐ Husband, wife, children and relatives

17 Goat ownership

- ☐ Husband only
- ☐ Wife only
- ☐ Children only
- ☐ Husband and wife only
- ☐ Husband, wife and children
- ☐ Relatives only
- ☐ Husband, wife, children and relatives

18. Status of the grazing area

- ☐ Increased
- ☐ Reduced
- ☐ Remained the same

19. Livestock mortality…………………………………………………………

20. Livestock diseases ………………………………………………………,,,,,

21. How many animals do you sell per year…………………………………......

22. Where do you sell………………………………Average Price……...……..

23. Who herds the animals a) cattle………………b)goats………………………

24. Grazing time Animals go out at …………..hrs Animals return at………hrs

25. Feeding strategies of cattle; Rain Season………………………..………..

Dry season……………………………..

26. Feeding strategies for Goats & sheep; Rain season…………………......

Dry season…………………….....

27. Is there any type of supplementary feeding given to cattle yes………no……

If yes what type…………………………………………………………...

28. Is there any type of supplementary feeding given to goats and sheep yes..no

If yes what type……………………………..

29. Source of water for home use; well ……river… dam ……. Borehole...........

30. Distance to water source………………………………………...........…..

31. Source of water for livestock; well ………river……dam …. Borehole………

32. Distance to water source…………………………………...……………...

Land Use Strategy

33. How do you graze/move animals away from the settlement;

i) during the wet season…………………………………………………

ii) During the dry season…………………………………………………

34. Give an indication of animal gain/performance (milk production during;

iii) during the wet season……………………..

iv) During the dry season……………………….....................................

35. Do you suffer restricted movement at any time yes…………….no………

If yes when/how**…………………………………………….....……………….**

Forage conservation

36. Do you do feed conservation yes……………..………….no………………

If no why…………………………………………………......…………..

If yes types of conservation used……………………………………………

……………………………………………………………………………

37. What type of pasture management practices do you carry out……………

…………………………………………………………………………………

Climate adaptation and Grasses/legumes use

38 Name the type of grasses/legumes which are important for grazing livestock

……………………………………………………………………………………

……………………………………………………………….............................

39. Which ones are the most important mention in order of importance beginning with the most important……………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

40. Which grasses/legumes are very important during long droughts…………………..

…………………………..

41. Which grasses/legumes are very important during floods…………………

…………………………………………………………………………..............

42. What are the other uses of grasses and legumes other than grazing animals

Name of grass/legume……………… .uses…………………………………

Name of grass/legume………………….uses…………………………………

Name of grass/legume………………..uses…………………………………

Name of grass/legume………………..uses…………………………………

Name of grass/legume………………..uses…………………………………

Climate adaptation and Browse use

43 Name the type of browse which are important for grazing livestock…………

……………………………………………………………....……………...…
…………………………………………………………………….......................

44 Which ones are the most important & mention in order of importance beginning with the most important…....……………………………………..

………………………………………………………………………………...........

………………………………………………………………………….................

45 Which browse types are very important during long droughts……………

……………………………………………………………………………......

....…

46. Which browse are very important during floods…...................................

……………………………………………………………………………...
....……………………….............................

47. What are the other uses of grasses and legumes other than grazing animals

Name of browse……………………….uses…………………………………

Name of browse……………………....uses…………………………………

Name of brows...................................uses…………………………………

Name of browse…………………........uses…………………………………

Name of browse...........................…..uses…………………………………

48. What management practices do you do to ensure good use of browse…………………………………………………………………………………
…………………………..

49. What are the problems with browse use……………………………………

……………………………………………………………………………......