POTENTIALS OF *ACACIA SENEGAL* (L.) WILD AS FODDER IN LIVESTOCK PRODUCTION IN BUKOMBE DISTRICT, SHINYANGA, TANZANIA

BY

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ABSTRACT

This study was conducted in Bukombe District which is one of the eight districts of Shinyanga Region, in Tanzania. The research was done in Mbogwe, Ushirombo and Runzewe forest reserves in the district. The aim was to assess the potentials of *Acacia senegal* as a source of fodder for livestock production. Sixty-nine circular plots with radius of 15 m, sampling intensity of 0.01% and sample size of 0.071 ha were used for determining the population and distribution of *Acacia senegal* trees. Samples of *Acacia senegal* leaves, pods, bark and gums were collected. Also, samples of different grass species were taken from the same plots at random using square quadrants. The study observed variation in abundance of *Acacia senegal* trees in Mbogwe, Ushirombo and Runzewe Forest Reserves with a mean of 70, 42, and 14 trees per ha respectively while the size distribution of *Acacia senegal* trees in those forest reserves for mean height was 5.3, 5.7 and 4.9 m and for mean diameter was 2.5, 2.4 and 2.4 cm respectively. There were variation in nutritive values from different parts of *Acacia senegal* tree where the leaves observed with highest nutrients contents in terms of DM, NFE, EE and ME with a mean value of 92.1%, 33.8%, 5.8% and 19.5% respectively as well as the highest content of Potassium with a mean value of 2.4%. The *Acacia senegal* tree had the highest percentage of proximal components compared to grass species. The tree had also high values of macro-mineral content such as calcium, phosphorus, sodium and potassium with a mean value of 0.8%, 0.3%, 0.2% and 1.9% respectively. It is concluded that, *Acacia senegal* trees could save as an alternative fodder resources for livestock. Therefore, strategic intervention should be put in place in the management of *Acacia senegal* as source of fodder.

DECLARATION

I, George James Sabuni, do hereby declare to the senate of Sokoine University of Agriculture that the work presented here is my original work and has not been submitted for a higher degree award in any other university.

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DEDICATION

The dissertation is dedicated to my wife Suzana, my beloved son and daughter, James and Siriel respectively.

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LIST OF ACRONYMS

A	-	Forest area in ha
AIACC	-	Assessment of Impacts and Adaptation of Climate Change
AOAC	-	Association of Official Analytical Chemists
BDC	-	Bukombe District Council
Ca	-	Calcium
CF	-	Crude Fiber
CP	-	Crude Protein
D	-	Inter-plot distance
DASP	-	Department of Animal Science and Production
DM	-	Dry Matter
EE	-	Ether Extract
EPA	-	Environmental Protection Agency
FAO	-	Food and Agriculture Organization of the United Nations
GDP	-	Gross Domestic Product
Ha	-	Hectare
IPCC	-	Intergovernmental Panel on Climate Change
K	-	Potassium
KARI	-	Kenya Agricultural Research Institute
Kg	-	Kilogram
M	-	Metre
ME	-	Metabolized Energy
Mg	-	Magnesium
MJ	-	Mega Joules
MNRT	-	Ministry of Natural Resources and Tourism

MWLD	-	Ministry of Water and Livestock Development
N	-	Number of the sample plots
Na	-	Sodium
NAS	-	National Academy of Science
NFE	-	Nitrogen Free Extract
NMD	-	National Meteorological Department
^{o}C	-	Degree Celsius
P	-	Phosphorus
Ps	-	Plot size
Si	-	Sampling intensity
SUA	-	Sokoine University of Agriculture
TA	-	Total Area of the forest in ha
THCL	-	Tanzania High Commission-London
TNW	-	Tanzania National Website
UNFCCC	-	United Nations Framework Convention on Climate Change
URT	-	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Climate changes are often aggravated by human-induced factors such as unsustainable agricultural practices, overgrazing and deforestation. Land degradation and shortage of forest products are, therefore, common and serious phenomena. Human, livestock population growth, climate change and variability are among the reasons causing increased scarcity of natural resources and increasing conflicts in many areas especially in developing countries like Tanzania. The global climate change is directly affecting the humankind and their environment.

This phenomenon has lead to global warming in which there has been additional temperature of between 3.2 to 7.2^0C in the 21^{st} century (IPCC, 2007). The increase in temperature can prolong crop-growing season in a region with relatively cool seasons, adversely affect crops in regions where summer heat already limits production, increase soil evaporation rates and increase the chances of severe drought (EPA, 2008).

Tanzania has a total land area of 886 037 km^2 of which 4% is arable land, 38% and 40% respectively is permanent pastures and woodland (URT, 2001). The country relies on the agricultural sector, which contributes 24.6 % of her Gross Domestic Product (GDP) (URT, 2010) and over 50% of export earnings (THCL, 2001).

The vegetation cover types of Tanzania can be categorized into forest cover (2.9%), woodland (39.6%), bush land (18.3%), grassland (20.5%), open land (0.2%), cultivated land (10.7%) and others (0.1%). The exceptionally high richness in the indigenous biodiversity gives the country the potential to deliver diverse forest products (Mziray, 1999). The literature shows a global outcry concerning the high rate of environmental deterioration (FAO, 2001), in which Tanzania was estimated to lose 2% of its forestland annually (URT, 1998). As a means of conserving these resources, the government reformed environmental policy objectives to ensure sustainable and equitable use of the resources to meet the basic needs of the present and future generation.

In some regions such as Dodoma, Tabora, Singida, Shinyanga and Manyara, *Acacia* species are essential to the survival of both people and animals. In these areas, there are hash climatic conditions, whereby *Acacia* species grow and become sources of fodder, timber, bee forage, fuel and gum as well as improving soil fertility through nitrogen fixation (Raddad and Luukkanen, 2007).

Acacia senegal is particularly interesting because it is a source of the multipurpose commodity gum-arabic, which is traded on both local and international markets. It is produced in several sub-Saharan African agricultural production systems particularly in Sudan (Mohamed, 2005; Seppälä *et al*., 2009). Also *A. senegal* is incorporated in the famous agro-forestry known as bush- fallow system of shifting cultivation.
This system ensures optimum and sustainable utilization of the natural resources, for the gum production and crop cultivation as well as livestock fodder (Seif el Din, 1981).

According to FAO (1983), *Acacia senegal* leaves and pods have adequate phosphorus content ranging from 0.12 to 0.15%, they are palatable to livestock with energy values of between 6.8 to 7.5MJkg^{-1} DM. In addition, Anderson and Wang (1991) documented that, dried and preserved seeds of *Acacia senegal* are used by people as vegetables. Improved management of semi-arid areas through promotion of adapted trees such as *A. senegal* is beneficial to the climate because it leads to carbon dioxide removal from the atmosphere and carbon storage, both above ground in biomass and in the soil below. Environmental sustainability can therefore be improved since forests and stable grasslands save as carbon sinks (EPA, 2008).

Soils are the largest terrestrial sink for carbon on the planet and the ability of the land to sequester carbon will depend largely on the type of vegetation cover and management practices (Seppälä *et al*., 2009). From their biomass and ecological requirements, *A. senegal* is a tree specie with potential for carbon sequestration in semi-arid areas (Seppälä *et al*., 2009). A shrub or tree is 2 to 6 m, occasionally up to 15 m in height with umbrella-shaped crown. It is very branched with many upright twigs (Ruffo *et al*., 2002) and FAO (1983) documented this tree to have an extensive lateral root system covering up to 500 m which according to Fagg and Allison (2004), represents up to 40% by weight of the total biomass.

Acacia senegal is very drought resistant and tolerates dry period of 8 to 11 months. The species prefer sandy soils, but grows also on slightly loamy sands. It is also noted by Backlund *et al*. (2008), that land restoration and land use changes that encourage the conservation and improvement of the environment can be effectively effected through modifications to grazing practices and incorporation of multipurpose trees including *A. senegal,* in marginal lands.

1.2 Problem statement and justification

Bukombe is among the poverty stricken districts of Tanzania, the poverty is exuberated since the district is located in the semi-arid agro-ecological regions of low potential for sustained arable farming due to frequent droughts and environmental degradation

(Ashimogo, 1995). Livestock production is common and the land is usually not supportive for pasture production particularly during dry seasons. In this region conflicts arise between farmers and pastoral communities as large populations of livestock immigrate to areas with adequate green pastures.

In recognizing the potential that exists in the natural vegetation resources and incorporating it in the development and conservation strategies Makonda (2003) describes the natural vegetation in this area to comprise mostly of *Acacia* species, promisingly, forming a potential zone for gum-arabic production. Unfortunately, the potentiality of *Acacia senegal* has never been fully utilized in Tanzania (FAO, 2001). Literature shows that a study on potentiality of *Acacia senegal* was done in Sudan which differs from Tanzania in terms of geographical location, soil characteristics and climate. In agropastoral areas of Tanzania *Acacia senegal* trees are cut down for wood fuel, fencing and building materials. The perceived value of *Acacia* species are therefore overridden by that of wood products (Makonda, 2003).

In Bukombe District, various domestic animals including cattle, goats and sheep are kept by the farmers. These livestock feed on *A. senegal* during dry period of the year due to shortage of feeds. The natural vegetations of this district comprise of *Acacia senegal* trees and some grass species. It is due to this background that, this study has been developed to assess the potentials of *A. senegal* in livestock production specifically in Bukombe district.

1.3 Objectives

1.3.1 General objective

To assess the potentials of *Acacia senegal* (L) Wild as a source of fodder to livestock production.

1.3.2 Specific objectives

i) To estimate abundance and size distribution of *Acacia senegal* in the study area.

ii) To determine the nutrient values of leaves, pods, gums and bark from *Acacia senegal*.

iii) To compare nutritive values of *Acacia senegal* with other fodders in the study area as potential feed resource for animals.

1.3.3 Research questions

i) What is the abundance and size distribution of *Acacia senegal* in the study area?

ii) What is the nutritive value present in pods, leaves, gum and bark from *A. senegal?*

iii) What is the nutritive value of natural existing fodder resource in the study area?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

This chapter reviews the nutritive values of *Acacia senegal* and other fodders as potential feed resources for livestock production and in smallholder systems as well as definition of some contemporary concepts such as climate change and adaptation.

2.2 Concepts and definitions

2.2.1 Climate change

Climate change was defined by Wilson (2006) as "the changes in the long-term trends in the average climate, such as changes in average temperatures". The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "any change in climate over a time, whether due to natural variability or as a result of human activities". In the United Nation Framework Convention on climate change (UNFCCC) usage, climate change refers to a change in climate that is attributable directly or indirectly to human activity, which alters atmospheric composition (Olmos, 2001).

Global average surface temperature has increased over the 20th Century by about 0.6^{o}C (Barber *et al.,* 2004). During this period of global temperature increase there has been a decrease in the extent of snow and ice cover, a rise in the average sea level and the heat content of the oceans, and a number of change in weather pattern that can also be associated directly or indirectly with the increasing temperatures and reduced the rainfall intensity (Barber *et al.,* 2004; CCSP, 2004; Majule *et al.*, 2004).

Climate variability refers to change in patterns, such as precipitation variables, weather and climate condition (Wilson, 2006). It is the variation around the average climate, including seasonal variations in atmospheric and ocean circulation such as the *El Nino*. According to Orindi and Murray (2005), climate variability is the shift from the normal experienced rainfall pattern of seasons to abnormal rainfall pattern. Some evidence of climate variability include the decline in food harvests and water resources due to prolonged drought and daily shift of seasons as well as too much and unexpected rainfall.

2.2.2 Effects of climate change at global and national levels

Climate change due to radioactive will warm the lower atmosphere and cool the stratosphere (IPCC, 1996). The rate of temperature increase will range between 0.2 and 0.5 ^{0}C per decade. Global average precipitation and evapotranspiration are estimated to increase by 3 to 15%.

According to Munishi *et al.* (2006), changes in climatological patterns have implication on hazards, whereby one of the major cause of these hazards at village, ward, division, district, region and national levels is attributed to climatic changes associated with prolonged heavy rainfall or drought. Three most identified hazards in the country are drought (47%), pest/plant diseases (30%) and floods (13%). These high ranked hazards have been classified as commonly occurring in a period of less than five years, and have a positive correlation to the predicted climatic changes.

2.2.3 Effects of climate change on livestock

Climatic and environmental changes have caused a decline in pasture/crop productivity, deterioration of water quality, quantity and loss of biodiversity. The increasing human/livestock population and other activities have resulted in change in land use, land cover, desertification and environmental degradation (AIACC, 2006). Variation in climate is one of the most significant problems facing livestock in the developing countries and the most vulnerable to impacts of climatic change are the rural areas (IPCC, 2001). Due to poor economic resources, the rural poor fail to adjust on long-term changes in climate variability (Orindi and Murray, 2005).

In Tanzania, climate change is likely to alter temperatures and distribution of rainfall, which contribute to sea level rise and increase the frequency and intensity of extreme weather events (Orindi and Murray, 2005). The intensity of drought and floods result in change growing seasons of pasture, crops with significant effects for soil productivity and water supply. These lead to irreversible impacts on biological diversity (AIACC, 2006).The ecological gradient that ranges from higher rainfall to lower rainfall potential where livelihood systems interact across the different zone have been affected hence influencing land management (Majule *et al.*, 2004). The severe drought that occurred in the country includes that of 1983 and 1994, which was followed by *El Nino* in 1997 – 98 (Majule *et al.*, 2004).

In livestock, adaptation is defined as “adjustment by the livestock to feed on abnormal feeding materials due to deficiency of normal fodder and pasture in their grazing area, because of changes in climatic condition system” (Olmos, 2001). It is the ability of the system to cope in order to absorb stress or impact and to recover. However, adaptation can be spontaneous can be carried out in response to change in conditions (IPCC, 1996; Olmos, 2001). In addition, adaptation to climate change can be defined as “process through which people, reduce the adverse effects of climate variability on their health and well-being, and take advantage of opportunities that their climatic environment provides” (Feenstra *et al.*, 1998). In arid zones all over the world, the potential of trees and shrubs as livestock feed is increasingly being recognized and more animals feed on shrubs and trees than a grass (Khan, 1965).

It is difficult, however, to lay down general rules about what makes a good browse species. It is initially important to know the relative nutritive value of grasses and shrub vegetation (FAO, 2005).

2.2.4 Livestock

Higher livestock densities, and the expansion of cash crop cultivation have resulted in acute fodder shortages especially during the long dry seasons (Skerman, 1968; Otsyina *et al* .,1993), as the grazing lands are being converted for cultivation, while livestock numbers remained the same, or increased.

Trees and shrubs not only provide fodder for the livestock but may also be useful in providing fuel. Although *Acacia* is primarily grown for fuel, its leaves and pods are used as fodder when other types of fodder are in short supply. Pods of *Acacia* provide a feed supplement and more critical during feed shortage periods. *Acacia* leaves are valued for their nutritive value and milk-improving quality during the cold months of the year, but their use must be restricted if the plants are to flower and produce pods (Khan, 1965).

Livestock is among the major agricultural sub-sectors in Tanzania. Out of the 4.9 million agricultural households, about 36% is keeping livestock (35% is engaged in both crop and livestock production while 1% is purely livestock keepers). The industry accounted for 5.9 % to total GDP in 2006, of which beef, dairy and other stock provided 40%, 30% and 30% respectively (Dotto, 1998). In Africa, Ethiopia is claimed to have largest livestock population while, Tanzania ranks third in livestock population and the major source of livestock feed comes from unimproved pasture, crop residues, rangelands and fallows (MWLD, 2004).

The primary objective of livestock policy in Tanzania is to improve food security of the nation, and improve the nation standard of nutrition by increasing output, quality and availability of milk and milk products, meat and hide and skin (MWLD, 2004). Out of the total 88.6 million hectares of land resource, 60 million hectares are rangelands suitable for livestock grazing, able to carry up to 20 million livestock units (Dotto, 1998).The number of livestock in Shinyanga region is reported as 4 575 266 (NSCA, 2002) as indicated in Table 1.

The region has got the largest population of cattle (2 679 532) in Tanzania followed by Mwanza, Dodoma, Singida, Arusha and Morogoro regions with about 1.7, 1.6, 1.4, 1.3 and 1.1 million cattle respectively. The largest population of cattle is found in the Eastern parts of Shinyanga region, in Bariadi, Meatu and Maswa districts.

Table 1: Livestock population in Shinyanga Region

Livestock category	**Population**
Cattle	2 679 532
Goats	1 328 947
Sheep	540 565
Donkey	26 222
Total	**4 575 266**

Source: NSCA (2002)

2.2.4.1 Livestock population in Bukombe District

Bukombe District is divided into three divisions (BDC, 2002) namely Mbogwe, Ushirombo and Runzewe divisions. The biggest livestock population is found in

Ushirombo and Mbogwe divisions within the district compared to other parts of the district as indicated in Table 2. Livestock are unequally distributed between and within both farmers and divisions.

Table 2: Livestock population in Bukombe District

Divisions	Wards	Cattle	Oxen	Donkey	Sheep	Goats
Mbogwe	Mbogwe	8975	4801	69	3614	6700
	Ilolangulu	12 475	1301	64	1923	11 113
	Ushirika	9834	3942	54	2410	12 271
	Nyasato	12 478	1298	68	2278	9794
Ushirombo	Ushirombo	12 673	1100	181	2618	10 074
	Bukombe	11 812	1964	77	2770	6280
	Iyogelo	10 973	2803	73	3526	5766
	Masumbwe	12 217	1559	67	3123	8283
	Iponya	11 628	2148	58	2618	11 211
	Lugunga	12 462	1321	74	3124	5955
	Bukandwe	10 641	3135	76	1873	7691
Runzewe	Runzewe	10 217	3559	64	4730	2853
	Uyovu	11 428	2348	71	2126	2852
	Ikungwigazi	11 354	2422	76	2117	12 210
Total		**159 167**	**33 701**	**1072**	**38 850**	**113 053**

Source: NSCA (2002)

2.2.5 Nutritive values of fodders

The nutritive value of the different diet is defined as a measure of its ability to maintain, promote growth or some other biological activities in the animal (Van Soest, 1982). Van Soest (1965) defines nutritive values as an indication of the contribution of food to the nutrient content of the diet. This value depends on the quantity of food, which is digested and absorbed. It also depends on the quantity of essential nutrients (carbohydrates protein, vitamin, mineral and fat). Whatever the physiological effects of feed or diet the nutritive value could, in a short term, affect intake and ingestibility of particular types of feed material (Anderson and Wieping 1990).

In addition, the nutritive value of fodders refers to its chemical composition, digestibility and the nature of digested products (Van Soest, 1965). However, Raymond (1969) classified nutritive value into three general components, namely, feed consumption, digestibility and energetic efficiency. Furthermore, Ulyatt (1973) divided nutritive value into the proportion that is digested or the apparent digestibility and the efficiency with which digested nutrients are utilized for maintenance and production.

The chemical composition of fodder refers to contents of protein, carbohydrates and minerals (Norton, 1982; Crowder and Chheda, 1982). Chemical composition is often used as an index of fodders' quality. High quality fodders provide protein, minerals and energy in direct proportion to the animal's requirement (Norton, 1982). Fodders differ considerably in their chemical composition depending upon their genotype, stage of growth, soil and climate condition (Mwakatundu, 1977).

The DM yield potential and nutritive value of pastures plants vary between families, genera, species, and even varieties or cultivar. The tropical grass species have a more efficient biochemical pathway compared to the temperate grass species. Whiteman, (1980); Crowder and Chheda, (1982) reported that, tropical grass species grow faster and accumulate more dry matter percentage compared to temperate grass species and tropical legume species. However, tropical legume species have higher nutritive values than grasses especially when harvested at the same stage of growth (Minson *et al.*, 1976; Kidunda 1988).

Dry matter of a fodder resource is composed of the organic and inorganic fraction. The organic compounds contain minerals elements, which are structural components, protein for example contain Sulphur. The implication of dry matter content has a direct implication in the amount of energy and other nutrients. Ash is the residue remaining after all the combustible material has been burned off (oxidized completely) in the furnace heated to 500 to 600 ^{0}C, in proximate analysis ashes are required to obtain other values whatever some mineral elements such as iodine and selenium may be volatile and are lost on ashing (AOAC ,1990).

Crude protein is a complex organic compound of high molecular weight, they contain Carbon, Hydrogen, Oxygen and Sulphur. It is not true protein because the method determines Nitrogen from sources other than protein such as free amino acid, amines and nucleic acid and the fractions is therefore designated as a crude protein. From nutrition point of view, crude proteins are applicable to ruminant species, which can efficiently utilize almost all forms of nitrogen (AOAC, 1990).

Crude fiber is made up primarily of plant structural carbohydrates such as cellulose and hemicelluloses but it also contains some lignin, a highly indigestible materials associated with the fibrous portion of plant tissues (AOAC, 1990). The fiber fractions of feeds have the greatest influence on the digestibility in both the amount and chemical composition.

Nitrogen free extract, is a misnomer in that no extract is involved. It is called N-free because ordinarily it would contain no nitrogen. Nitrogen free extract is made up primarily of readily available carbohydrates, such as the sugars and starches, but it may also contain some hemicelluloses and lignin particularly in such feedstuffs as forages, (AOAC, 1990). Metabolized energy is the energy that acquired by the animal from feedstuff and its importance is for maintenance, growth and production for example milk production for ruminant and egg production for chicken (AOAC ,1990).

Major mineral elements include the essential macro elements such as Calcium, Magnesium, Phosphorus, Sodium and Potassium. These elements are important for animal body functioning which include supporting living cells and tissue fluids (blood) and they are essential for the activities of enzyme system in the nerves impulses. They are determined by atomic absorption spectroscopy (AOAC, 1990).

2.3 *Acacia senegal*

2.3.1 Description

Acacia senegal belongs to the family Fabaceae syn. Leguminosae (Mimosoideae) and it is known with different vernacular names in different areas for example: In Tanzania, it is known as Kikwata (Swahili) and Igwata (Sukuma) (FAO, 1983; Booth and Wickens, 1988; Coe and Beentje, 1991) as was cited by Makonda (2003). Generally, *Acacia* species is a pantropical and subtropical genus with species abundant throughout Africa, America, Asia and Australia. They thrive in adverse range of habitat and environments. Many species are well adapted to the semi-arid and savanna regions but equally others survive in most forest and riverine areas, tolerating both high pH and waterlogged soils. With such diversity, *Acacia* has considerable potential in a range of livestock and agroforestry (Bennison and Paterson, 1993).

In Africa, some naturally occurring *A. senegal* has become important in pastoral and agropastoral systems, while imported spp have become commercially accepted. Trees provide fodder and shade for livestock, improve soil fertility through Nitrogen fixation and the production of the leaf litter and stabilize veils. The species provide edible fruits, seeds, gum arabic, timber, fuel, construction and fencing poles/materials (Kessy, 1987).

The species forms a deciduous thorny in areas receiving 120 mm of rainfall but may reach 3 to 6 m where rainfall is between 300 and 500 mm. In favourable sites, the tree may reach upto 15 m in height (FAO, 1983; Booth and Wickens 1988). Its stem is irregular in form and often highly branched. It has characteristic sets of prickles on the branches and stems. Usually the tree has three thorny where by middle one hooked downward and the two laterals thorny curved upward (FAO, 1983; Booth and Wickens 1988; Coe and Beentje, 1991).

The leaves are bipinnate usually hairy, only 3 to 6 pairs of leaflets and leaflets are grey-green, small and narrow. Flowers are creamy spikes, fragrant; usually develop before the rainy season. Fruits are in the form of pods and are variable, thin and flat, pointed at ends, oblong, soft, grey-yellow becomes papery brown, veins clear, with 3 to 6 flat seeds (Ruffo *et al*., 2002).

The bark is light-grey or light-brown not papery or peeling, smooth in young tree but slightly scaly and somewhat creviced in old trees (FAO, 1983). The author described further that the tree's branches are much ramified, difficult to penetrate when trees are close together, and the spines make the gum harvesting difficult. The twigs are dark-grey to grey-brown (Brenan, 1959).

2.3.2 Ecology

Acacia senegal grows in tropical and sub-tropical, arid and semi-arid regions and it is very drought resistant. Trees survive in the most adverse conditions, subject to hot winds and sandstorms on the poorest soils of rock and sand. *Acacia senegal* occurs naturally in areas with an annual rainfall of 100 to 800 mm with 7 to 11 dry months per year. It also grows in some highland sites in Rwanda and Kenya which may receive as much as 1000 mm of rain (Majule *et al.*, 2004).

The species is mainly found to thrive best in areas where the average annual temperatures vary from 25 to 30°C, although it can withstand up to temperatures of 45°C. Over most of its natural range *Acacia senegal* is sensitive to frost, although in Asia it occurs in areas with minimum temperatures as low as –2.5 to –5°C. The altitude range of *Acacia senegal* is 0 to 2 000 m. It is associated with a variety of vegetation types ranging from semi-desert grassland to *anogeissus* woodland (Majule *et al.*, 2004).

Sandy soils are preferred, particularly those of fossil dunes in the Sahel, but it will also grow on loamy sand, on rocky hill slopes and even on clay plains, provided they are well drained and rainfall is at least around 600 mm per year, compensating for the lower available soil moisture. It will not grow on mineral soils or strongly leached ferrous soils. A coarse texture is preferred. There is no correlation of soil organic matter content with abundance of *Acacia senegal*. Free drainage is essential and water logging is not tolerated at all. The pH of the soil may range from slightly acid to moderately alkaline (Wickens, *et al.*, 1995).

2.3.3 Distribution and uses

The tree is dominant component of the wood vegetation on light sandy soils (FAO, 1999). It is characteristic of the African dry lands, in area receiving rainfall of between 250 and 750 mm per year and mean annual temperatures of between 25 and 27^{o}C.

Acacia senegal is a widespread species occurring natural from Mauritania to Sudan, Ethiopia, Somalia, east Africa and extends southwards to Mozambique and South Africa. It also occurs beyond the Red sea in Arabia, Sinai desert, Iran, West India and Oman (Booth and Wickens, 1988; Barnes *et al*., 1997*)*.

Acacia senegal variety occurs naturally over the large area referred to as the Gum Belt which covers about 45% of Sudan and is the only variety that is being cultivated species for the production of gum in the Sudan and other Sahelian countries (FAO, 1999). According to Booth and Wickens (1988) the highest density of *Acacia* species across the Kenya, Tanzania as well as Zimbabwe and South Africa borders.

In addition to producing gum, the wood of *Acacia senegal*, whose calorific value is 3 200 Kcal. Kg $^{-1}$ (NAS, 1980) is sought after for meeting wood fuel requirements (NAS, 1979; Kaba, 1989; Badi *et al.,* 1989). Badi *et al., (*1989) reported that, *A. senegal* provides most of the fuel wood supply in western Sudan.

Many *Acacia* species form spiny, slow growing scrub, which provides protection against soil erosion caused by wind and rain. Their tolerance to harsh conditions makes them valuable for stabilization and revegetation of difficult sites. *Acacia armata, A. glaucescens, A. polyacantha* and *A. suaveolens* tolerate salty and so can be used to stabilize coastal sand dunes (NAS, 1980).

The *Acacia senegal* tree is an important source of charcoal in arid regions and used for both domestic fuel and tobacco curing. In addition, it also provides poles for mining and agriculture in many parts of the world. As timber, *Acacia* wood is extremely durable and although it is hard to work, it finishes well. Smaller species provide wood, which is used to make implements handles, pipes and furniture while larger species, are used for paneling, boats and musical instruments (NAS, 1980).

The wood is considered heavy and tough so is employed in agricultural implements, roofing, lining wells, timber framing of huts and poles (NAS, 1979; FAO, 1983). In Sudan, *Acacia senegal* is incorporated in a bush-fallow of shifting cultivation, described by Seif el Din (1981), for improvement of soil fertility during the fallow period. Being a legume, it has the ability to harbour nitrogen-fixation bacteria. The resource is also useful for protecting the soil from erosion and for curbing desertification (Sharawi, 1987; Booth and Wickens, 1988; Seif el Din and Zarroug, 1998).

The long lateral roots of *Acacia senegal* can be used as twine either directly or after beating them to extract the fibres (FAO, 1983). Gum arabic, an important emulsifier, protective colloid, adhesive and binder, is produced in commercially exploitable quantities from *A. senegal,* the principal historical source, and more recent from *A. senegal* and some 20 other species of *Acacia*. Gum arabic is used in foods, pharmaceuticals, cosmetics, adhesives, paints, polishes and inks and in lithography, photography, textile sizing. Moreover *Acacia senegal* is valued as an ornamental (Bennison and Paterson, 1993).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location

The research was conducted in Bukombe District, which is one of the eight districts of Shinyanga Region in Tanzania. The geographical coordinates of Bukombe District are 3° 00' - 4° 30' South, 31° 00' - 32° 15' East. The district is bordered to the East by Kahama District (Shinyanga), to the North by Biharamulo District (Kagera), to the West by Kibondo District (Kigoma) and to the South by Urambo District (Tabora). The details are in Fig.1.

3.1.2 Topography and soil characteristics

Bukombe District lies between 400 to 2300 m above sea level. The area is characterized by flat areas, gently undulating hills separated by mbuga plains, gentle slopes and most rivers are seasonal. Soils are mainly clay loam with vertic properties and tremendous variations from hill top to flat areas. The district is semi arid, characterized by fluctuating moisture deficit as the average monthly evapo-transpiration is substantially exceeds precipitation throughout the year (BDC, 2010).

3.1.3 Vegetation

The main vegetations are deciduous and dominated by *Acacia, Commiphora* and *Euphorbia* species (White, 1983). However, due to severe deforestation, the land is mostly bare, eroded and difficult to re-afforest. The natural vegetation of the area has changed to secondary wooded grassland but still dominated by the same tree species (Backeus *et al.,* 1996). The main species are *Acacia senegal, A. nilotica, A. drepanolobium, Commiphora africana, C. schimperi* and *C. mollis* (MNRT, 1996).

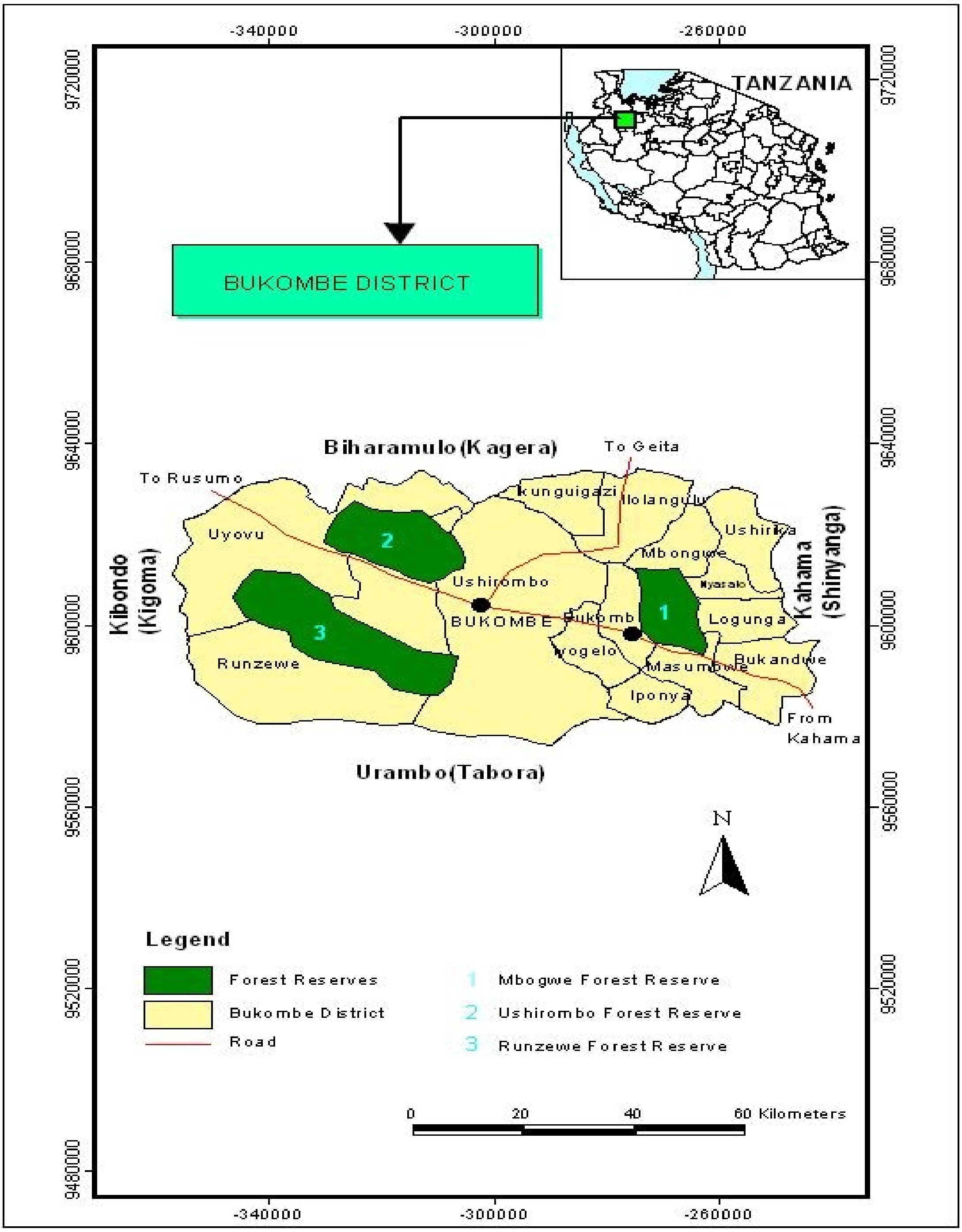

Figure 1: **Map showing the location of the surveyed forest reserves in Bukombe District**

3.1.4 Climate

The annual temperatures range between 22ºC to 32ºC in the cold and hot season respectively. The district experiences a rainfall pattern normally falling from November to April with mean annual rainfall ranging from 900 mm – 1200 mm. The district is located in arid and semi arid agro-ecological zones with three ecological zones in which *Acacia senegal* trees grow naturally namely the higher-land area, the intermediate and lowland (NMD, 2001). Evapotranspiration is four times more than the average rainfall received in the area making famine a current danger (Christianson *et al.*, 1991). These areas are of low potential for sustaining established and natural pasture, as severe droughts occur at intervals of 5 to 9 years (BDC, 2010).

3.1.5 Demography and economic activities

The district has three administrative divisions namely Mbogwe, Ushirombo and Runzewe divisions, 14 wards and 122 villages. Bukombe District has a total area of 10 482 square kilometers. It has a potential arable land of about 619 km^2 and forest reserve of 6 289 km^2. The main economic activity of the district is agriculture, livestock keeping, small-scale mining and official employment (BDC, 2010). The area has a human population of 396 423 (National Bureau of Statistics, 2002). The ethnic group of the district is dominantly the Sukuma tribe and other tribes include Sumbwa, Ha, and Haya.

The research area comprised of three forest reserves namely Mbogwe, Ushirombo and Runzewe forest reserves. Variations in climatic conditions are based on topography, soil characteristics, vegetation cover (BDC, 2010).

According to NSCA (2002) livestock census, the district had 159 167 cattle, 33 701 oxen, 1 072 donkeys, 38 850 sheep and 113 053 goats. The major cultivated crops include maize, sorghum, millet, cassava, cotton and rice. Over 80% of the population own and manage livestock on communal rangelands (NSCA, 2002).

3.2 Methods

3.2.1 Sampling

Stratified sampling approach was employed to include all the three forest reserves, namely Mbogwe, Ushirombo, and Runzewe forest reserves in which *Acacia senegal* is found. The sampling unit for this study was the vegetation area of the district. The strata were forest reserves comprising high land, intermediate and low land. Estimation of distribution and abundance of *A. senegal* as well as identification of existing natural fodder resource in the plots was done. Sample plots were established along transects whose number was determined through the following formula;-

$$N = (TA * Si) / (Ps * 100)$$

Where: N= number of sample plots,

TA= Total area of the forest

Si = Sampling intensity

Ps= Plot size

Inter transect or inter-plot distance was obtained through the following formular

$$D = \sqrt{(Af * 10000)}/N$$

Where: N= Inter-plot distance (m), Af= forest area, N=Number of plots.

3.2.2 Data collection

3.2.2.1 Abundance and size distribution of *Acacia senegal*

Determination of abundance and size distribution were done in three-district forest reserves and maps were used to identify areas of each forest reserve. Sixty-nine circular plots with radius of 15 m, sampling intensity of 0.01% and sample size of 0.071 ha were used for determining the population and size distribution of *Acacia senegal* trees. Sample plots were laid along the transects with inter-plot distance of 2.7 km for Runzewe, and 2.6 km for Mbogwe and Ushirombo each. The number of trees was counted and average population of *A. senegal* calculated for each forest reserve. The size distribution of the fodder trees were determined by measuring diameter at breast height (Dbh) using tape measure and the height of the tree was measured using hypsometer.

3.2.2.2 Nutritive values of *Acacia senegal*

Thirty trees of *A. senegal* from each forest reserves were used for collection of fodder specimen namely; leaves, pods, gums and bark then, were labeled and transported to SUA Department of Animal Science and Production laboratory for proximal analysis. Proximate analysis is a combination of analytical procedures developed over a century ago. It is intended for the routine description of feedstuffs. Dry matter determination was done through placing the test material in an oven heated at 100 to 105°C until all the free water has evaporated.

Determination of Crude Protein was done according to Kjeldah using block digestion and steam distillation. Determination of Crude Fiber was done by using Ankom technology. While, determination of Ether Extract was done by using Soxtec technology and Nitrogen Free Extract was estimated through calculation whereby DM-ASH-CP-CF-EE= NFE, Metabolized Energy and Mineral Contents were analyzed by an out flow analyzer (AOAC, 1990).

3.2.2.3 Nutritive values of existing natural fodder resources

Samples of natural existing fodder were collected from three rangeland namely; Mbogwe, Ushirombo and Runzewe reserves. The sample were collected from different indigenous grass species namely; *Hyparrhenia rufa, Panicum maximum, Cynodon dactylon, Chloris gayana, Urochloa mosambicensis, Sporobolus pyramidaris, Leucine indica,* in the same plots where samples of the *Acacia senegal* tree were taken. The sampled grass species were used for proximate chemical composition determinations. The samples were collected at random in the plots using a square quadrant (Crowder and Chheda, 1982; Kidunda, 1996).

3.3 Data analysis

The data on abundance, size distribution, chemical composition of different natural grass species and nutritive composition of fodder from *Acacia senegal* tree (leaves, pods, bark and gums) and grass species were analyzed by using Microsoft Excel computer program. Moreover, the means were analyzed by the Analysis of Variance (ANOVA) techniques using Complete Randomized Design (CRD) for comparing *A. senegal* parts. In comparison of nutritive values of *A. senegal* with grass species t-test was used.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Abundance and size distribution of *Acacia senegal*

4.1.1 Abundance

The abundance of *Acacia senegal* ranged from 69 to 71 trees per ha and the mean number of trees for Mbogwe Forest Reserve was 70 ± 1 trees per ha. In Ushirombo Forest Reserve, the abundance ranged from 41 to 43 trees per ha with a mean of 42 ± 0.8 trees per ha. While, in Runzewe Forest Reserve it ranged from 13 to 15 trees per ha with a mean of 14 ± 0.6 trees per ha Table 3. These results are on the lower side compared with those of Makonda (2003) who reported a mean of 168 ± 69 trees ha^{-1} for Babati District, and 116 ± 107 trees ha^{-1} in Singida Rural District.

Table 3: Abundance and size distribution of *Acacia senegal* in Bukombe District

Forest Reserve	Number of trees/ha	Height (m)	Diameter (cm)
Mbogwe	70 ± 0.95	5.3 ± 1.7	2.5 ± 0.8
Ushirombo	42 ± 0.8	5.7 ± 0.9	2.4 ± 0.7
Runzewe	14 ± 0.6	4.9 ± 0.8	2.4 ± 0.7

Mbogwe Forest Reserve with an area of 9000 ha had the largest number of *A. senegal* trees followed by Ushirombo and Runzewe Forest Reserves which had 7600 ha and 32 000 ha respectively. In general, the survey shows that *A. senegal* trees are sparsely distributed in the study area.

4.1.2 Size distribution

The height of *A. senegal* ranged from 3.6 m to 7 m with a mean of 5.3 ± 1.7 m in Mbogwe Forest Reserve. In Ushirombo Forest Reserve, the height ranged from 4.7 m to 6.6 m with a mean of 5.7 ± 0.9 m. The height of *A. senegal* in Runzewe Forest Reserve ranged from 4.1 m to 5.7 m with mean of 4.9 ± 0.8 m.

The diameter of the trees for Mbogwe Forest Reserve ranged from 1.7 cm to 3.3 cm with a mean diameter of 2.5 ± 0.8 cm. Ushirombo Forest Reserve had the diameter ranging from 1.7 cm to 3.1 cm with a mean diameter of 2.4 ± 0.7 cm. In Runzewe Forest Reserve, the diameter was similar that of Ushirombo Forest Reserve with a mean of 2.4 ± 0.7 cm (Table 3).

The major causes of variation in height and diameter of *A. senegal* might be due to soil properties, age of trees, utilization due large number of livestock and rainfall distribution. The results on height and diameter above concur with Philip (1994) as cited by Makonda (2003).

4.1.3 Grass species composition

Grass species compositions for the different forest reserves in Bukombe District are summarized in Table 4. The dominant grass species were *Hyparrhenia rufa* (12.5%), *Panicum maximum* (10.2%), *Cynodon dactylon* (8.4%), *Chloris gayana* (8.2%), *Urochloa mosambicensis* (8.1%), *Sporobolus pyramidaris* (7.6%), and *Leucina indica* (5.6%). Other grass species with relatively low frequencies were *Sorghum sudanese*, *Digitaria milanjiana* and *Dactyloctenium aegyptium*.

The observed grass species compositions at relatively high frequencies in almost all the surveyed forest reserves are in conformity with the findings by Issae (1997). However, the observed variations in the grass species composition might have been due to the nature of the soils, moisture contents, soils' pH and climate condition. Most of the grass species such as *Digitaria milanjiana, Sorghum sudanese and Dactyloctenium aegyptium* were found to be dominant in black cotton soil while *Panicum maximum* and *Chloris gayana* were abundant in clay loam soils. These findings also concur with the report by Issae (1997).

Table 4: Dominant grass species in Bukombe District

Grass species	Forest Reserve			Mean
	Mbogwe	Ushirombo	Runzewe	
Hyparrhenia rufa	4.2	3.8	4.5	12.5
Panicum maximum	3.1	3.0	4.0	10.2
Cynodon dactylon	2.1	2.7	3.5	8.4
Chloris gayana	2.5	3.1	2.6	8.2
Urochloa mosambicensis	3.8	2.1	2.15	8.1
Sporobolus pyramidaris	2.6	2.5	2.5	7.6
Leucina indica	1.1	2.2	2.3	5.6
Digitaria milanjiana	1.2	3.1	2.2	2.2
Sorghum sudanese	1.2	2.3	3.2	2.2
Dactyloctenium aegyptium	1.3	0.1	2.3	1.2

The figures in the Table are frequencies of occurrence

4.2 Nutritive values of *Acacia senegal* parts

The results show that a mean Dry Matter (DM) content for leaves in all forest reserves was 92.1 ± 0.9, mean DM content of pods was 90.8 ± 0.1 while that of bark was 91.4 ± 0.2. In addition, the mean DM content of gums was 90.2 ± 0.1 in Table 5. Results show that there is a small difference in DM content between leaves, pods, bark and gum ($p<0.01$).

Table 5: Nutritive values of *Acacia senegal* parts in Bukombe District

Nutrients (%)	Leaves		Pods		Bark		Gums	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DM	92.1	0.9	90.8	0.1	91.4	0.2	90.2	0.1
ASH	90.2	0.1	89.8	0.1	90.3	0.1	88.9	0.1
CP	22.1	0.1	43.4	0.2	11.3	0.2	8.2	0.1
CF	28.3	0.2	13.9	1.9	44.5	2	0	0
NFE	33.8	0.1	25.2	0.1	27.5	1.5	15.6	1.6

EE	5.8	0.6	2.6	1.2	1.9	0.4	3.4	0.7
ME	19.5	0.6	8.6	0.9	16.2	0.7	7.3	0.6
Ca	1.2	0.1	0.6	0.2	0.8	0.1	0.6	0.1
Mg	0.2	0.1	0.2	0.1	0.6	0.1	0.4	0.2
P	0.2	0.1	0.3	0.1	0.6	0.1	0.3	0.1
Na	0.1	0	0.3	0.1	0.02	0.01	0.4	0.1
K	2.4	1	2.4	0.2	1.4	0.1	1.1	0.1

Where DM-Dry Matter; CP-Crude Protein; CF-Crude Fiber; NFE- Nitrogen Free Extract; EE- Ether extract; ME-Metabolized Energy and SD-Standard Deviation.

The ash mean content of the bark part from fodder tree resource was 90.3 ± 0.1% followed by leaves 90.2 ± 3%, pods 89.8 ± 0.1%, and gums 88.9 ± 0.1%. The above results are in agreement with Tanner *et al.* (1990) who reported a range of ash content from 88.6 to 90.1% with a mean of 90 ± 0.3% for the leaves. The possible source of minor variation may be influenced by oven temperature intensity during sample preparation in the laboratory.

The results further shows that, the mean Crude Protein (CP) content of the leaves of *A. senegal* was 22.1 ± 0.1%,while that of pods was 43.4 ± 0.2%. The results obtained were similar to those reported by Skerman *et al.* (1988) whereby CP content of *A. senegal* fodder ranged from 16.8 to 39%. The data provide a good indication of the nutritive value of *Acacia* species as valuable sources of protein particularly when compared with mature grasses. Moreover, the crude protein level in a forage dry matter during the dry season can fall down to 4% or less (Skerman *et al.*, 1988). The results show that pods have the highest crude protein of all parts of *Acacia senegal*. In comparison Ndemanisho *et al.* (1988) reported crude protein content of *Leucaena leucocephala* pods to range from 21 to 34% with high minerals and vitamins. *Leucaena leucocephala* was also reported to posses' high ability to provide by-pass nutrients (protein, starch and lipid) absorbed from small intestines (Norton, 1994).

The mean Crude Fiber (CF) content of the bark, leaves and pods was 44.5 ± 2%, 28.3 ± 0.2% and 13.9 ± 1.9% respectively. The findings fall within the range of 8 to 46% as was reported by Goodchild and McMeniman (1987). The results indicate that the bark part of *A. senegal* is very high in CF when compared with other parts of the tree. In comparison, review by Robertson (1988), Tergas *et al.* (1989), Jones (1994), Norton (1994) and Karachi (1998) have shown that the CF of *Leucaena leucocephala* was 34.3%.

A mean Nitrogen Free Extract (NFE) content of leaves, bark, pods and gums was 33.8 ± 0.1%, 27.5 ± 1.5%, 25.2 ± 0.1% and 15.6 ± 1.6% respectively. The information above shows that leaves part in *A. senegal* has higher NFE when compared with other parts of the tree. According to Gohl (1981) the range of NFE content was 32 to 66% for leaves with average of 48.6% while the range of NFE content of pods were 31 to 67% with mean of 51.9%. The possible source of variation of the results could be due to variation in soil fertility as it was observed by Henzell (1977) and Wilson (2006). Furthermore, Henzell (1977) observed that healthy and high quality tree fodder thrive only on soils well supplied with N, P, Ca, Mg and K. The author documented also that most tropical soils are highly weathered, leached and deficient in mineral nutrients, as such can explain observed differences in nutrient contents.

Ether Extract (EE) content of the tree leaves, pods, bark and gums were 5.8 ± 0.6%, 2.6 ± 1.2%, 1.9 ± 0.4%, and 3.4 ± 0.7% respectively. In comparison, the range of EE content was 2 to 13% of the dry matter with a mean of 3.3% for leaves while range of EE content of the pods was 1 to 3% with a mean of 1.7%, as was reported by Goodchild and McMeniman (1987).

The results also show that leaves from *A. senegal* had substantially higher metabolized energy 19.5± 0.6% when compared with bark 16.2 ± 0.7%, pods 8.6 ± 0.9%, and gums 7.3 ± 0.6%. Despite the high Metabolized Energy, the bark is less utilized by ruminant animals compared to the other parts. According to Norton (1982), the mineral balance concentration and nature of the minerals, in fodders vary with plant species, parts of the plant, stage of growth and mineral availability in the soil. Fertilizer may increase plant growth rate and mineral content, but differences between species are evident when optimal fertilizers are provided (KARI, 1999). In the current study, a mean calcium content of the leaves, pods, bark and gums were 1.2±0.1%, 0.6 ± 0.2%, 0.8 ± 0.1% and 0.6 ± 0.1% respectively (Table 5).

In general, the findings show that leaves had the highest calcium content compared to other parts. In this regard, leaves can provide substantial amount of calcium when other feedstuffs are not available. On the other hand, a mean content of magnesium, phosphorus, sodium, potassium in the gums was 0.4 ± 0.2%, 0.3±0.1%, 0.4±0.1% and 1.1±0.1% respectively. The findings indicate that gums had high potassium content when compared with the other parts. Furthermore, pods and leaves seemed to have lower mineral contents compared with bark and gums. These results are similar to those reported by Jones (1994) and Karachi (1998). Moreover, Norton (1994) reported major mineral content of 26, 2, 13, 23 and 6 gm/kg for phosphorus, sodium, potassium, calcium and magnesium respectively. Karachi (1998) reported slight deferent results for minerals, whereby Calcium and Phosphorus ranged from 0.2 to 1.8 and 0.14 to 0.22% respectively.

Comparative analysis of nutrients in *Acacia senegal* parts shows that there was significant difference in nutrient composition. In addition, using a two way analysis of variance, there was a statistically significant difference at ($p<0.01$) in the variation of nutrient contents between tree parts. This is in agreement with observations made by Kidunda (1988) within the rangeland of Dodoma. The variations between tree parts may be attributable to differences age of the tree and micro environmental factors such as temperature, soil moisture, and soil pH. Soil structure determines the availability of both soil moisture and nutrients and also influences aeration and soil temperature.

4.3 Comparison of nutritive values of *Acacia senegal* with the grass species

4.3.1 Dry matter

Evaluation of feeding value of *A. senegal* in terms of chemical composition shows that it is a highly nutritious fodder (Table 6).

Table 6: Comparison of nutritive values of *Acacia senegal* with the grass species

	Item	Nutrient content (%)						
		DM	ASH	CP	CF	NFE	EE	ME
A. senegal	Leaves	92.1	90.2	22.1	28.3	33.8	5.8	19.5
	Pods	90.8	89.8	43.4	13.9	25.2	2.6	8.6
	Bark	91.4	90.3	11.3	44.5	27.5	1.9	16.2
	Gums	90.2	88.9	8.2	NA	15.6	3.4	7.3
	Mean	91.1	89.8	21.3	21.7	25.5	3.4	12.9
Grasses	*Leucina indica*	95.3	83.6	19.2	18.2	20.5	2.3	7.4
	Hyparrhenia rufa	95.3	89.9	23.1	23.4	26.2	4.5	13.7
	Sporobolus pyramidaris	95.3	85.6	17.4	21.2	21.1	2.1	10.1
	Urochloa mosambicensis	95.6	84.9	14.3	18.1	22.3	2.2	11.7
	Panicum maximum	95.6	87.1	18.6	19.3	23.7	2.4	9.8
	Chloris gayana	95.1	88	19.3	17.9	20.2	2.1	8.9
	Cynodon dactylon	95	87.4	20.7	19.5	19.8	3.6	10.6
	Mean	95.3	86.6	18.9	19.7	22	2.7	10.3

Where DM-Dry Matter; CP-Crude Protein; CF-Crude Fiber; NFE- Nitrogen Free Extract; EE-Ether extract; ME-Metabolized Energy.

The Dry matter (DM) content ranged from 90.2% in gums to 92.1% in leaves with a mean DM content of 91.1%. The DM content is higher than that of other *Acacia* species such as *Acacia modesta* and *Acacia nilotica* whose DM content means for leaves were 53.4% and 44.8% respectively (AOAC, 1990; Abdulrazak *et al.*, 2000). However, the DM content of *Acacia senegal* was nearly similar to grass species such as *Leucina indica*, *Hyparrhenia rufa, Sporobolus pyramidaris, Urochloa mosambicensis, Panicum maximum, Chloris gayana* and *Cynodon dactylon* (Table 6). While McDowell (1974) reported DM content of 93.3% for *Stenotaphrum secundatum*, in contrast, Kidunda (1988) reported the DM content of four tropical grass species viz. *Pennisetum purpureum*, *Chloris gayana*, *Tripsacum laxum* and *Brichiaria brizantha* to range between 3 to 18.3% with a mean DM content of 15% among tropical grass species. The author showed a significant increase in DM percentage of the grasses with advancing stage of growth. According to Kidunda (1988), the dry matter percentage and nutritive value of grass species are influenced by the frequency, intensity of defoliation and the interval between harvests.

4.3.2 Ash

The ash content range of *Acacia senegal* was between 88.9% for gums to 90.3% for bark with a mean of 89.8%. Duke (1983) reported the mean ash content of the *Acacia tortilis* to be 85.7% for pods to 89.9% for leaves while the range of ash content of the grass species was 83.6% for *Leucina indica* to 89.9% for *Hyparrhenia rufa* with mean ash content of 86.6% for the grass species. In addition, KARI (1999) reported proximate composition of *Chloris gayana* ash content to be 83.8%. The results are similar to those reported for *Gliricidia sepium* and *Leucaena leucocephala* where the ash content ranged from 81 to 85.5% with a mean ash content of 82.3% (Kidunda, 1988).

4.3.3 Crude Protein

The Crude Protein (CP) content of *Acacia senegal* ranged from 8.2% for gums to 43.4% for pods with a mean CP content of 21.3%. Duke (1983) reported *Acacia tortilis* to have a CP content of 17.3% for pods while, Karachi (1998) reported a CP content of 16.7% for *Faidherbia albida*. For grass species the CP content ranged from 14.3% for *Urochloa mosambicensis* to 23.1% for *Hyparrhenia rufa*. Based on the findings, there was a minor difference in CP content between *Acacia senegal* and the grass species. In comparison, Ndemanisho *et al.* (1988) reported proximate composition of CP values of *Leucaena leucocephala* to range from 20.3 to 34%.

4.3.4 Crude Fiber

The Crude Fiber (CF) content of *Acacia senegal* ranged from 13.9% for pods to 44.5% for bark with a mean of 21.7% while those of grass species ranged between 17.9% for *Chloris gayana* to 23.4% for *Hyparrhenia rufa* with mean CF content of 19.7% for all grass species analysed. Moreover, KARI (1999), documented CF to be 36% for the Rhodes grass. Literature by FAO (1999), shows that CF levels of *Acacia senegal* are relatively high (15 to 47.2%) compared with other *Acacia* species such as *Acacia modesta* 22.8% for leaves, and *Acacia nilotica* 13.9% for leaves. In comparison, *Acacia senegal* bark has higher CF content than the phyllodenous *Acacia* species which have marginally higher CF value than bipinnate species (Tanner *et al.*, 1990). However, for phyllodenous species, the lower nutritive value is offset by both the higher biomass yield and the retention of the phyllodes throughout the dry season, when bipinnate species tend to shed their leaves (Skerman *et al*., 1988).

4.3.5 Nitrogen Free Extract

The Nitrogen Free Extract (NFE) content range in *Acacia senegal* was 15.6% for gums to 33.8% for bark with a mean of 25.5% while the grasses' range NFE content was 19.8% for *Cynodon dactylon* to 26.2% for *Hyparrhenia rufa* with a mean NFE content of 22%. These results are in agreement with those reported by Dharia *et al.*, (1993). The authors documented the range of NFE content of *Gliricidia sepium* to range from 38.8% to 45.5% with a mean of 42.2%. The findings indicate that there is a slight difference between *Acacia senegal* trees and grass species, the variation may be due to soil properties and climatic condition.

4.3.6 Ether Extract

The Ether Extract (EE) content range of the fodder tree was 1.9% for bark to 5.8% for leaves with mean of 3.4% compared to EE content range of the grass species of 2.1% for *Sporobolus pyramidaris* to 4.5% of *Hyparrhenia rufa* with a mean of 2.7% for grass species. These results concur with FAO (1999) which reported 2.1% for *Pennisetum purpureum* with a mean of 4.5%. The reasons for differences could be soil moisture and stress which lead to reduce grass growth through reduced rate of leaf development (Whiteman, 1980).

4.3.7 Metabolized Energy

The Metabolized Energy (ME) content of *A. senegal* tree ranged from 7.3% for gums to 19.5% for leaves with a mean of 12.9%. The ME content of grasses was 7.4% for *Leucaena indica* to 13.7% for *Hyparrhenia rufa* with a mean content of 10.3%. Abdulrazak *et al.* (2000) reported ME of *Chloris gayana* hay to be 7.4% which is similar to the result of *Leucaena indica.*

Statistically, there was significant difference in nutrients content between *Acacia senegal,* fodder resource and grass species ($p<0.01$). This implies that, *Acacia senegal* fodder resource can be better substitute for most grass species especially during dry season where there is deficit of pastures for livestock.

4.4 Comparison of contents of macro-mineral in *Acacia senegal* and grass species

4.4.1 Minerals

The range in major mineral elements found in *Acacia senegal* were calcium 0.6% for gums to 1.2% for leaves, magnesium 0.2% for pods to 0.5% for bark. Phosphorus levels were 0.2% for leaves to 0.5% for bark and sodium was 0.02% for bark to 0.4% for gums whereas potassium ranged from 1.1% for gums to 2.5% for pods (Table 7).

Table 7: Comparison of contents of macro-mineral in *Acacia senegal* and grass species

	Item	Mineral content (%)				
		Ca	Mg	P	Na	K
A. senegal	Leaves	1.2	0.2	0.2	0.1	2.4
	Pods	0.6	0.2	0.3	0.3	2.5
	Bark	0.8	0.5	0.5	0.02	1.4
	Gums	0.6	0.3	0.3	0.4	1.1
	Mean	0.8	0.3	0.3	0.2	1.9
Grass species	*Leucina indica*	1.2	0.2	0.1	0.1	0.9
	Hyparrhenia rufa	0.6	0.4	0.2	0.1	0.7
	Sporobolus pyramidaris	0.4	0.3	0.2	0.1	0.9
	Urochloa mosambicensis	0.7	0.4	0.2	0.1	0.8
	Panicum maximum	0.6	0.2	0.1	0.1	2.7
	Chloris gayana	0.3	0.2	0.1	0.1	0.8
	Cynodon dactylon	0.8	0.2	0.2	0.1	1.8
	Mean	0.7	0.3	0.2	0.1	1.2

Ca-Calcium; Mg-Magnesium; P-Phosphorus; Na-Sodium and K-Potassium

The mean of the major mineral elements found in *Acacia senegal* were 0.8, 0.3, 0.3, 0.2 and 1.9% for calcium, magnesium, sodium, phosphorus and potassium, respectively. MOAC (1997) reported other *Acacia* species macro minerals in *Acacia tortilis* to be 0.6, 0.2, 0.3, 0.1 and 1.3% for calcium, magnesium, sodium, phosphorus, and potassium respectively. The results conform to those reported by Timberlake (1980) in *Acacia robusta*.

Dharia *et al*. (1993) reported other fodder plants such as *Gliricidia sepium* to have calcium content ranging from 1.7% for bark to 2.4% for leaves. In comparison calcium content of the grass species ranged from 0.3% for *Chloris gayana* to 1.2% for *Leucina indica*. Magnesium ranged from 0.2% for *Leucina indica* to 0.4% for *Urochloa mosambicensis.* The observation indicated phosphorus to range from 0.1% for *Panicum maximum* to 0.2% for *Sporobolus pyramidaris*.

In addition, sodium contents ranged from 0.1% for *Urochloa mosambicensis* to 0.1% for *Panicum maximum,* whereas potassium content ranged between 0.7% for *Hyparrhenia rufa* to 2.7% for *Panicum maximum*.

According to Perdomo *et al.* (1977), calcium content found in *Panicum maximum* ranged from 0.4% to 0.5% with a mean of 0.2 while magnesium content ranged between 0.3 to 0.7% with a mean of 0.3% for *Cynodon plectostachyum*. These results agree with those reported by McDowell *et al.* (1974) who expressed phosphorus content of *Brachiaria brizantha* grass to range from 0.2 to 0.4% with a mean of 0.2%. Moreover, sodium content of *Brachiaria brizantha* ranged from 0.2% to 0.4% with a mean of 0.3% (McDowell *et al.*, 1974).

Based on AOAC (1990) findings, *Panicum maximum* grass had potassium content ranging from 1.1% to 1.7% with mean of 1.2%. According to observations, it is obvious that there were slight variations of major mineral element contents among *Acacia senegal* fodder trees and grass species when compared with other feed stuffs such as *Brachiaria brizantha*, *Gliricidia sepium* and *Acacia tortilis*.

In this study the t-test analysis revealed significant difference between major mineral elements in *Acacia senegal* and grass species ($p<0.01$). This indicated that, livestock can acquire adequate major mineral elements when *Acacia senegal* trees fodder resources are used to feed livestock instead of natural grass species especially during dry period. Most of the natural existing grass species are not drought resistant in comparison to *Acacia senegal* trees. Therefore, the fodder trees should be well conserved and fed to the livestock during dry season

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study observed variation in abundance of *Acacia senegal* trees in Mbogwe, Ushirombo and Runzewe forest reserves with a mean of 70, 42, and 14 trees per ha respectively while the size distribution of *Acacia senegal* trees in those forest reserves for mean height was 5.3, 5.7 and 4.9 m and for mean diameter at breast height was 2.5, 2.4 and 2.4 cm respectively.

Among the different parts of *Acacia senegal* tree leaves were observed to have the highest nutritive value in terms of DM, NFE, EE and ME with a mean value of 92.1%, 33.8%, 5.8% and 19.5% respectively. Likewise leaves had the highest content of Potassium that was similar to that of pods with a mean value of 2.4%.

The study further revealed that, in comparison to grass species, *Acacia senegal* had the highest macro-mineral contents as well as Ash, CP, CF, NFE, EE and ME.

The results indicate that *Acacia senegal* trees are good substitute of natural grass species and could save as supplementary feed for livestock during dry season owing to its resistance to drought compared to many grass species.

5.2 Recommendations

Livestock keepers should incorporate *Acacia senegal* in agroforestry system under silvopastoral technology whereby the trees are integrated with livestock in the same land unit. This could ensure availability and sustainability of the fodder trees for the livestock during dry season where there could be shortage supply of livestock feed stuffs.

Based on the adequate availability of nutrient and mineral contents found in *Acacia senegal* parts, the farmers should be made aware of the importance of *Acacia senegal* as an alternative source of fodder during the shortage of livestock feed so as to maintain their livestock in terms of health and production.

Therefore, intentional and strategic decision should be imposed in the management of *Acacia senegal* trees as an alternative fodder resource for animal during the shortage of grass resource.

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APPENDICES

Appendix 1: Nutritive values of *Acacia senegal* parts in Bukombe District

Parts	Nutrients %	Forest reserves				
		Mbogwe	Ushirombo	Runzewe	Mean	STDEV
Leaves	Dry matter	91.07	92.47	92.71	92.08	0.88
Pods		90.85	90.63	90.92	90.80	0.14
Bark		91.15	91.50	91.63	91.42	0.24
Gums		90.2	90.2	90.3	90.23	0.05
	ash					
Leaves		90.3	90.2	90.2	90.23	0.05
Pods		89.96	89.78	89.75	89.83	0.11
Bark		90.3	90.4	90.3	90.33	0.11
Gums		88.73	88.96	88.97	88.88	0.05
	Crude protein					
Leaves		22.1	22.2	22	22.1	0.1
Pods		43.6	43.2	43.4	43.4	0.2
Bark		11.1	11.4	11.3	11.26	0.15
Gums		8.2	8.3	8.1	8.2	0.1
	Crude fiber					
Leaves		28.3	28.5	28.2	28.33	0.15
Pods		12.8	15.9	12.9	13.86	1.76
Bark		42.9	46.7	43.8	44.46	1.98
Gums		0	0	0	0	0
	Nitrogen free extract					
Leaves		33.8	33.9	33.8	33.83	0.05
Pods		25.2	25.3	25.1	25.2	0.1
Bark		29.1	27.3	26.2	27.53	1.46
Gums		14.6	17.4	14.8	15.6	1.56
	Ether extract					
Leaves		5.3	5.6	6.5	5.8	0.62
Pods		1.5	3.9	2.3	2.56	1.22
Bark		2.3	1.6	1.7	1.86	0.37
Gums		2.8	4.1	3.2	3.36	0.66
	Metabolized energy					
Leaves		20.1	19.6	18.9	19.53	0.60
Pods		7.8	9.5	8.6	8.63	0.85
Bark		15.6	17	16	16.2	0.72
Gums		8	7.1	6.8	7.3	0.62

Appendix 2: Macro-mineral contents of *Acacia senegal* parts in Bukombe District

	Minerals %	Forest Reserves				
Parts		Mbogwe	Ushirombo	Runzewe	Mean	Std dev
Leaves	Calcium	1.3	1.1	1.2	1.2	0.1
Podes		0.5	0.8	0.6	0.63	0.15
Bark		0.8	0.9	0.7	0.8	0.1
Gums		0.6	0.6	0.7	0.63	0.05
	Magnesium					
Leaves		0.2	0.1	0.3	0.2	0.1
Podes		0.3	0.2	0.1	0.2	0.1
Bark		0.5	0.7	0.6	0.6	0.1
Gums		0.4	0.2	0.5	0.36	0.15
	Phosphorus					
Leaves		0.3	0.1	0.2	0.2	0.1
Podes		0.2	0.4	0.4	0.33	0.11
Bark		0.6	0.5	0.7	0.6	0.1
Gums		0.4	0.4	0.2	0.33	0.11
	Sodium					
Leaves		0.1	0.1	0.1	0.1	1.7E-17
Podes		0.2	0.4	0.4	0.33	0.11
Bark		0.02	0.03	0.01	0.02	0.01
Gums		0.4	0.3	0.5	0.4	0.1
	Potassium					
Leaves		3.5	1.5	2.3	2.43	1.01
Podes		2.3	2.6	2.3	2.4	0.17
Bark		1.4	1.5	1.3	1.4	0.1
Gums		1.1	1.2	1.1	1.13	0.05

Appendix 3: ANOVA for nutritive values of *Acacia senegal* parts in Bukombe District

Dry matter

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	5.75	3	1.91	10.74	0.01	4.75
Columns	0.68	2	0.34	1.92	0.22	5.14
Error	1.07	6	0.17			
Total	7.51	11				

Ash

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3.91	3	1.30	105.59	1.39-05	4.75
Columns	0.01	2	0.01	0.07	0.92	5.14
Error	0.07	6	0.01			
Total	3.99	11				

Crude protein

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	2283.94	3	761.31	2947 0.22	6.83E-13	4.75
Columns	0.011	2	0.01	0.22	0.80	5.14
Error	0.15	6	0.02			
Total	2284.10	11				

Crude fiber

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3283.70	3	1094.56	984.86	1.81E-08	4.75

Columns	7.47	2	3.73	3.36	0.10	5.14
Error	6.66	6	1.11			
Total	3297.84	1 1				

Nitrogen free extract

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	515.01	3	171.67	145.34	5.44E-06	4.75
Columns	2.10	2	1.05	0.89	0.45	5.14
Error	7.08	6	1.18			
Total	524.20	11				

Ether extract

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	26.42	3	8.80	14.78	0.01	4.75
Columns	1.365	2	0.68	1.14	0.37	5.14
Error	3.575	6	0.59			
Total	31.36	11				

Metabolized energy

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	313.36	3	104.45	213.77	1.73E-06	4.75
Columns	1.06	2	0.53	1.08	0.39	5.14
Error	2.93	6	0.48			
Total	317.35	11				

Appendix 4: ANOVA for macro-mineral of *Acacia senegal* parts in Bukombe District

Calcium

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.64	3	0.21	14.84	0.01	4.75
Columns	0.01	2	0.01	0.23	0.80	5.14
Error	0.08	6	0.01			
Total	0.73	11				

Magnesium

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.32	3	0.10	6.78	0.02	4.75
Columns	0.01	2	0.01	0.36	0.70	5.14
Error	0.09	6	0.02			
Total	0.42	11				

Phosphorus

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.25	3	0.08	5.52	0.03	4.75
Columns	0.01	2	0.01	0.05	0.94	5.14
Error	0.09	6	0.02			
Total	0.346666667	11				

Sodium

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.29	3	0.09	16.50	0.01	4.75
Columns	0.01	2	0.01	0.88	0.45	5.14
Error	0.03	6	0.01			
Total	0.34	11				

Potassium

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	4.07	3	1.35	4.57	0.05	4.75
Columns	0.33	2	0.16	0.55	0.59	5.14
Error	1.78	6	0.29			
Total	6.18	11				

Appendix 5: Comparison of nutrients of *Acacia senegal* and grass species

	Variable 1	*Variable 2*
Mean	22.43	21.5
Variance	1098.31	1125.4
Observations	12	12
Pearson Correlation	0.99	
Hypothesized Mean Difference	0	
df	11	
t Stat	1.56	
P(T<=t) one-tail	0.07	
t Critical one-tail	1.79	
P(T<=t) two-tail	0.14	
t Critical two-tail	2.20	