# ASSESSMENT OF FORAGE LEGUMES FOR RANGELAND IMPROVEMENT IN THE NORTHERN GUINEA SAVANNA OF NIGERIA

**BY**

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## DECLARATION

I declare that the work in the dissertation entitled " Assessment of forage legumes for rangeland improvement in the Northern Guinea Savanna of Nigeria" has been performed by me in the rangeland of the National Animal Production Research Institute, Ahmadu Bello University, Shika, Zaria, under the supervision of Prof. M.S. Kallah, Prof. A.M. Adamu and Prof. C.A.M. Lakpini,

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any University

TANKO, Roger Joshua February 26, 2014

Roger Joshua Tanko _____ _____

Signature Date

## CERTIFICATION

This Thesis titled: **ASSESSMENT OF FORAGE LEGUMES FOR RANGELAND IMPROVEMENT IN THE NORTHERN GUINEA SAVANNA OF NIGERIA** by Roger Joshua TANKO meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This piece of work is dedicated to the loving memory of my late brothers Mr. Dickens Danjuma Jimen, Mr. Mamman Jimen and Mr. Yakubu. Tanko. It was their sacrifices that brought me thus far.

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## ABSTRACT

A three year trial (2004-2006) was conducted to assess the performance of three forage legumes, *Stylosanthes hamata(*L) Taub. cv Verano, *Chamaecrista rotundifolia* (Pers) Grenne cv Wynn and *Centrosema pascuorum* Mart. ex Benth (Centurion) cv Cavalcade in range rehabilitation. The first phase of the trial covered a period of sixteen months when the feasibility of range improvement by strip-sowing of the selected forage legumes into natural pastures was tested. Data on legume establishment, forage dry matter yield were collected from the strip-sown legumes and the natural pastures. The first phase was followed by a second one where Bunaji bulls were introduced to graze the treatments continuously over the next 12 months. The grazing animals were weighed fortnightly to monitor liveweight changes while the body condition score were recorded on a monthly basis. In the final year, persistency and spread of the different forage legumes were assessed. In the year of establishment, *S. hamata* recorded the highest stand count of 117 stands/$m^2$, with lower counts of 65 stands/$m^2$ for *C. pascuorum* and 25 stands/$m^2$ for *C. rotundifolia*. The *S. hamata* stand count was significantly higher ($P<0.01$) than that of either *C. pascuorum* or *C. rotundifolia*. In the second year following establishment, stand count in both *S. hamata* and *C. pascuorum* dropped while *C. rotundifolia* increased to 67 stands/$m^2$. The stand counts in *S. hamata* and *C. pascuorum* further decreased in the third year while *C. rotundifolia* stand count increased. Regeneration from seed from the legumes tested was 100% in *C. pascuorum*, 99.9% in *C. rotundfoilia* and 87.6% in *S. hamata.* In the third year, *C. rotundifolia* was found to have spread beyond its sown strips. Dry matter yields from the strips of the sown legume at commencement of grazing was highest in *S. hamata* strips (1.4t DM/ha)

than *C. rotundifolia* (1.1t DM/ ha) and *C. pascuorum* (0.9t DM/ha). The dry matter yield from the native pasture alone was 3.0 t DM/ha. In the grazing trial, paddocks were stocked at 4 Bunaji bulls /ha. The animals grazed from 9:00 am to 5:00 pm over a one year grazing cycle. Weight gain was highest in animals on *S. hamata* treatment than those on *C. rotundifolia*, with the least gain recorded in animals on *C. pascuorum* treatment. However, there was no significant difference due to treatment. Similarly body condition scores, which ranged between 3.30±0.09 to 3.53 ± 0.09 were not significantly different ($P>0.05$) in the treatments. The results of this study, therefore, indicate that *C. rotundifolia* has the potential for use in re-seeding degraded rangelands. It has the capacity to colonize areas faster than either *S. hamata* or *C. pascuorum. C. pascuorum* has the disadvantage of being very susceptible to attacks by various pests which prevented it from setting seed and subsequent regeneration in the open strip-sown range site. It is recommended that *Chamaecrista rotundifolia* be further tested in the rehabilitation of the degraded rangelands in the other Savanna ecological zones.

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## ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| ATP | Adenosine Triphosphate |
| BCS | Body Condition Score |
| CGIAR | Consultative Group on international Agricultural Research |
| CSIRO | Commonwealth Scientific and Industrial Research Organization |
| DM | Dry matter |
| DMRT | Duncan's Multiple Range Test |
| FAO | Food and Agricultural Organization |
| FMEN | Federal Ministry of Environment of Nigeria |
| GDP | Gross Domestic Product |
| GLM | General Linear Model |
| ha | Hectare |
| ICA | |
| ILRI | International Livestock Research Institute |
| INFORSE | International Network For Sustainable Energy |
| IVDMD | *In-vitro* Dry Matter Digestibility |
| kg | Kilogram |
| LOS | Level of Significance |
| $m^2$ | Square meters |
| N | Nitrogen |
| NAPRI | National Animal Production Research Institute |
| NAS | National Academy of Science |
| NLPD | National Livestock Projects Division |
| NS | Not Significant |
| P | Phosphorus |
| SAP | Structural Adjustment Programme |
| SAS | Statistical Analysis Systems |
| SEM | Standard Error of Mean |
| SSCA | |
| SSP | Single Superphosphate |
| t | Tons |
| TLU | Tropical Livestock Unit (an animal weighing 250kg) |
| UN | United Nations |
| WCED | World Commission on Environment and Development |
| $^oC$ | Degrees Centigrade |
| % | Per cent |

# CHAPTER 1

## 1.0 INTRODUCTION

### 1.1 ARABLE AND LIVESTOCK AGRICULTURE IN NIGERIA

Before Nigeria attained independence in 1960, agriculture was the leading sector of the economy, accounting for more than 50% of the total GDP and more than 75% of export earnings (Aregheore, 2005). It was the nation's bedrock for development until petroleum was discovered and exploited soon after independence from colonial Britain. The development of the petroleum industry in the late 1960s and 1970s radically transformed Nigeria from an agricultural based economy to a major oil exporter. The dramatic fall in international prices for petroleum in 1986 induced government to institute a two-year Structural Adjustment Program (SAP). The programme was aimed at expanding non-oil exports, reducing import of goods that could be manufactured locally and increasing the role of private sector participation in agriculture so as to achieve self-sufficiency in food (Aregheore, 2005).

Since the mid 1980's, many other countries of sub-Saharan Africa have been implementing the structural adjustment programmes (SAP) aimed at rectifying severe macro-economic problems, including falling export earnings, worsening balance of payments, mounting debts and declining economic growth (Misana *et al.,* 1996). Reductions in cereal imports and resurgence of public and private investment in agriculture resulted in a sharp recovery in production (FAO, 2001). Consequently, in countries that have implemented SAP, a major effect, among others, has been higher crop prices (Misana *et al.,* 1996). The net results of this were upsurge in land clearance to

open new lands for crop cultivation and reduction in surface area and habitat for animals while increasing marginalization of grazing to less productive lands. Thus, although there was steady growth in the production of both staple and cash crops since 1990, the supply of animal products has been declining over the past two decades. The demand for animal products, on the other hand, has been increasing as a result of increases in population and urbanization. Nigeria still remains a net importer of livestock and livestock products (Aregheore, 2005). The introduction of the SAP, which resulted in massive devaluation of the local currency continued to increase the expenditure on import of food and live animals as demand could not be met by local production (FMEN, 2001).

Almost all over the world rangelands are recognized as significant baseline resource in the livestock industry. This is more so on the continents of Africa, Australia, North America and South America where vast expanses of territory provide habitat and grazing for livestock and wild life. Rangelands are home to some 200 million people in the tropics and support about a billion domestic animals (Heady and Heady, 1982; ILRI, 1998). For all practical purposes, ruminant livestock production in Nigeria is in the hands of pastoralists who own over 90% of the stock holdings. The stocks are mainly reared under transhumant system of grazing over large expanses of rangelands. Under this production system the livestock rely on the natural rangeland forages with little or no supplementation for their nourishment year-round.

Despite the significant contribution of rangeland to the socio-economic lives of the inhabitants of developing countries, the resource is often abused and neglected in terms of planned utilization, development and management for sustainability (Kallah, 1999).

Pamo and Pieper (2000) noted a number of factors and developments which are placing increasing strains on rangeland resources, prominent among which is the rapidly growing human population and its associated stresses. The greatest challenge on what is left of the rangeland is the limited vegetative cover and capabilities in biomass production that can match the increasing demand and feed requirements of the grazing animals to be sustained in a given area (Hodgson, 1975).

Although the deterioration of the Sub-Saharan rangelands is a subject of great concern and extensive study, no blueprint has been produced which can accommodate the great diversity of natural, environmental and socio-economic conditions encountered in the management of the resources (Pamo and Pieper, 2000). Models introduced from temperate regions into tropical Sub-Saharan region before and after independence from colonial control have failed to improve range productivity (Jahnke 1982; Scoones 1995). Factors militating against the success of the models were social, economic, cultural and above all lack of good understanding of the functioning process of the system (Brumby, 1987; Preston and Murgueitio 1994; Pamo and Pieper 2000).

Sub-Saharan countries need to face the challenge of increasing degradation of rangelands and effectively deal with the management of open-access resources at disequilibrium (Ellis, 1995). This is necessary if livestock production must be improved and sustained in the millennium ahead. A wealth of information and knowledge in the range sciences and experiences from other regions could be borrowed and adapted to provide basis for alleviating some of the constraints (Barnes 1985).

The introduction of productive, nutritious, persistent plant species particularly legumes into the range had shown promise in that direction. Legumes have wide scope for restoring stability of feed resources in degraded landscape (Conner *et al*. 1998). Landscapes with extreme loss of soil and nutrients which could not otherwise be rejuvenated through improved grazing management alone may be restored by applying a combination of land terrain modifications and the introduction of adapted forage species to stabilize the system. Legumes introduction has been suggested as a low-cost, socially integratable restoration technology which can induce landscape alterations and allow grazed ecosystems to stabilize (Conner *et al*. 1998). The most suitable legume would have to be one that would withstand grazing, incessant fires and capable of high seed yield that can spread through the native range easily and colonize large areas naturally. In the final outcome, such species would be expected to improve grassland primary productivity to prevent further land degradation and increase productivity in the grazing animals especially during the dry season.

## 1.2 HYPOTHESIS

This study was carried out on the basis of the following hypotheses:

**$H_0$**: Three legumes introduced into native range will not differ in their ability to establish, contribute substantially to the dry matter production, increase animal production, persist and colonize the native range

**$H_a$**: Three legumes introduced into native range will differ in their ability to establish, contribute substantially to dry matter production, increase animal production, persist and colonize the native rangeland

## 1.3 OBJECTIVES

The broad objective of the trial was to identify suitable forage legume species for strip-sowing into the native rangeland of the Northern Guinea Savanna to improve productivity of the native rangeland, subject to open access utilization. The specific objectives were as follows:

i) To determine the ability of three introduced legumes to establish successfully in the native rangeland

ii) To evaluate the dry matter production capacity of the three legumes in the native rangeland

iii) To determine effect of the legumes on animals grazing the pastures and

iv) To assess the ability of the legumes to persist and colonize the native rangeland.

# CHAPTER 2

## 2.0 LITERATURE REVIEW

### 2.1 RANGE LIVESTOCK PRODUCTION

Rangelands are defined as large areas of land which support native plants growing in association with each other and suitable mainly for grazing purposes (Heady and Heady 1982). Land areas that fit this definition are estimated to cover about 47% - 51% of the earth's land surface, and occur in all continents and many larger islands of the World. Almost half of the world's rangelands lie within the tropics and sub-tropics between latitudes $23^{o}$ N and S of the Equator (Crowder and Chheda 1982; Mearns 1997). Mankind has secured livelihood from these communal or open-access natural resources from time immemorial. Hunters, gatherers, agriculturists, pastoralists and their animals obtain their habitat, food and other needs from open-access shared resources.

In the less humid tropical regions of the world, hundreds of millions of people depend directly on livestock-based activities (Preston and Murgueitio, 1994). Animals furnish more than one-fourth of the world's total value of agricultural products. The International Livestock Research Institute (ILRI, 1998) reported that there were 650 million cattle, sheep and goats in Africa, some 500 million in Latin America and the Caribbean and over 120 million in North America. The report also showed that throughout the developing world, rangelands provide 90 - 100% of the nutrients consumed by domestic livestock. It is not only in developing countries that livestock production depends on natural rangelands, as even in the industrialized nations, the beef and mutton industry is

built on resources derived from native and/or improved rangelands. It is reported that in the United States of America (USA), forages and roughages provide over 80% of the feed used to produce beef (ILRI, 1998).

Grassland ecosystems support people in various ways. As productive engines which support our livestock and wildlife, rangeland ecosystems provide everything from the water we drink to the food we eat and the fiber we use for clothing, paper or lumber. Unfortunately, nearly every measure used to assess the health of ecosystems tells us that society is drawing on them more than ever and degrading them at an accelerating pace (White *et al*., 2000). Within the last half of the 20$^{th}$ century, human activities have changed ecosystems more rapidly and extensively than in any comparable period of history. The net result had been substantial and largely irreversible losses in the variety of life on earth (White *et al*. 2000).

Rangelands, which were hitherto the traditional grazing sites for livestock and wildlife, are being encroached by competing land use demands like urban development and cultivation of crops. Almost one third of land on the earth surface is now under urban area development and cultivation for producing food and raw materials with the greatest loss being to conversion into arable agricultural areas (Robin *et. al*, 2000; Irwin and Ranganathan, 2007).

The conversion of natural grassland to agricultural land has dramatic effect on ecosystems. The native vegetation is conventionally removed and replaced with farm crops; while soil is exposed lessening its water-holding capacity and increasing its vulnerability to wind and water erosion. More significantly, the addition of fertilizers and

pesticides induce changes in soil composition and nutrient dynamics. When native grasslands are converted to farm lands, some native flora and fauna are able to survive and continue to reproduce in the modified environment. However, in many cases some species fail to reproduce successfully, resulting in loss of diversity. Similarly reduction in surface area for grazing due to farmland and other infrastructural developments necessitates the concentration of large herds of livestock on smaller, fragile land areas leading to overstocking which ultimately results in overgrazing and land degradation. The magnitude of environmental degradation and its subsequent effects due to overgrazing and haphazard exploitation of rangelands and forestry resources overwhelm the indigenous people who previously used to live harmoniously with these vital environmental resources (Curtis and Ruddy, 1990). This further aggravates the ecological imbalances with loss in biological diversity and productivity. Under such circumstances some form of developmental interventions would be required if grazing resources are to supply the necessary conditions for optimal livestock production that can cope up with rising human demands for animal-derived protein and industrial raw materials.

While grassland ecosystems still exist on every continent and cover approximately 41 percent of earth's land area, many types of grassland are best characterized as "fragments" than as "vast expanses" of land. Road networks are increasingly breaking large tracts of grasslands into pieces, while invasive species and human induced fires are changing grassland composition and extent (White et al. 2000). Yet natural pastures will continue to be the source of the bulk of ruminant feed for some time to come (Preston, 1995). Estimates put the extent of the grassland distribution around the world as 19.5%

in Central and Eastern Africa, 89.9% in North America, 76.0% in South America, 39.0% in Oceania and 21.4% in Asia (White *et al*. 2000).

Africa's grazing systems are characterized by agro-pastoralism and transhumance. Such systems were apparently sustainable in the past when there was low population density, with little pressure on the natural resource base and opportunities to move from degraded areas to new territories or to the adaptive practice of pastoralist to herd camels and goats instead of cattle. The systems have, however, been destabilized by "development" practices which have removed former "density-dependent" constraints through veterinary care, reduction in tribal raiding (Ellis and Swift, 1988). The impact of this destabilization was demonstrated in the case of Dodoma region of Tanzania (Christiansson *et al.*, 1987). Explosive growth of the population resulted in increasing areas of rangeland being diverted to cropping. At the same time, the livestock herds of the pastoralists were also increasing. The outcome was uncontrolled over-grazing of the non-cultivable areas, leading to severe land degradation, threatening total ecological collapse of the region. The seriousness of the situation resulted in the initiation of a unique programme, the Hifadhi Ardhi Dodoma – Dodoma Region Soil Conservation Project (HADO Project). This programme has been acclaimed to be of far reaching success in the rehabilitation of the degraded grazing lands (Christiansson *et al.*, 1987).

Traditional farming systems are often indicted in accelerating soil degradation and release of greenhouse gases to the atmosphere, while leading to weed invasions, impoverished post-fire climax vegetative ecosystems, and loss of biodiversity (Borlaug and Dowswell, 1995). The reports by Oldeman *et al.* (1990) suggest that almost 2 billion

ha of land worldwide have been degraded in the past 45 years (1945 - 1990), equivalent to about 17% of vegetated soils. Further, about 300 million ha of this land has suffered extreme degradation such that their original biotic functions are damaged and reclamation may be costly if not impossible. It is estimated that two-thirds of the world's degraded lands are found in Asia and Africa. The continued threat to the world's land resources is exacerbated by the need to reduce poverty (Buresh *et al.*, 1997).

It has been estimated that at least 25 million tonnes of soil is lost per year in erosion (Dover and Talbot, 1987). The FAO projected a global loss of productivity of rain fed cropland by 29% for the period 1975-2000 (FAO, 1984). On per capita basis, Brown and Wolf (1984) estimated a global decline of cropland per person by 19% between 1984 and 2000 and a decline in top soil of 32% per person. This is claimed as good indication that the process of soil loss would eventually undermine the world economy if not prevented. If the present trends continue, food insecurity, malnutrition, and resource degradation will increase, and by 2020, it is conceivable that Africa will need to import between 50 and 70 million t of food stuffs annually to meet the demands of the increased population (Dyson, 1995; FAO, 1996). While Africa may not have the economic resources to produce such huge volumes of food on a commercial basis, the international community may not be willing to provide it as concessional sales or food aid (Quinones *et al.*, 1997). This could put the African sub-region in a precarious situation and therefore calls for a rethink of how the land resource of the region is being used and how to reverse some of the negative trends.

One of the consequences of uncontrolled use of land is desertification. The rangelands are worst affected. Desertification is occurring at moderate or high levels in 1.9 million hectares (18%) of irrigated croplands, 48.86 million hectares (61 %) of rain-fed croplands, and 995.08 million hectares (74%) of rangelands (INFORSE, 1998). The annual rate of desertification is about 10% in arid lands, 1% in semi-arid lands and 0.1% in dry sub-humid lands leading to an annual increase of lands affected as follows: 156.9 million ha in arid areas, 23.0 million ha in semi-arid areas and 1.3 million ha in dry sub-humid areas, making a total of 181.2 million ha in the dry lands of the world. These figures give an average rate of current desertification of 3.5% per year (Chamshama and Nduwayezu, 2002).

Although land degradation occurs throughout the world, it is more acute in Africa, especially Sub-Saharan region. The phenomenon is characterized by decreasing food production per capita with increasing levels of poverty and malnutrition. Poverty is one of the main underlying factors contributing to soil fertility depletion (Rowe *et al*. 1994; Quinones *et al.*, 1997). Poverty-led environmental degradation is responsible for degradation of marginal lands which are subjected to deforestation, overgrazing of fragile rangelands, and cultivation of steep slopes, resulting in soil erosion, flooding and loss of vegetative cover.

Land degradation is observed in many parts of the developing world, especially in the sub-humid zone of Sub Saharan Africa. While many rural communities have evolved comparatively sustainable forms of resource use, many others are compelled by circumstances, often beyond their control, to exploit the open rangeland for short-term

gains (Rowe *et al.*, 1994). Most Africans are rural and agriculture is their mainstay. Thus agricultural development must, therefore, be the central strategy for economic growth and poverty alleviation (Birdsall, 1995). According to Cleaver and Schreiber (1994) and Quinones *et al.* (1997) hunger, poverty and environmental degradation are intimately correlated. This implies that any action towards minimizing environmental degradation will assist in the reduction of poverty and hunger as well.

Researchers concerned with developing sustainable livestock-based production systems in the tropics must be prepared to approach the problem in a multi-disciplinary fashion. Agronomic knowledge is an essential prelude to being able to use a particular plant as a livestock feed (Preston, 1995). Thus in developing new "alternative" feed resources, learning how to grow them and sustain their production will have a higher priority initially than characterizing their nutritive value.

## 2.2 OVERVIEW OF LIVESTOCK PRODUCTION

Livestock are domesticated animals reared in an agricultural setting for the production of food, fibre, traction or a combination of purposes. The rearing may be set for subsistence or for profit as a component of agriculture. It has been practiced in many societies, since the transition to farming from hunter-gatherer lifestyle.

Since prehistoric times, majority of Africans have been farmers and herders who raised crops and livestock for subsistence. In many cases, livestock provide the only means of survival in a harsh environment not suitable for other type of agricultural use. In addition, livestock constitute an investment unaffected by inflation that pays a significant

dividend not only in terms of low cost production but also in terms of growth (Newman *et. al*. 2007). The main categories of domestic livestock of the world are cattle, goats, sheep, camels, poultry, pigs and equines. Cattle and sheep together dominate the animal populations in Asia, Africa and Oceania, however, the populations of cattle, sheep and goats are quite similar in Europe. In North, Central and South America cattle dominate, while goats are primarily found in Asia (59%) and Africa (34%), and 41% of sheep are found in Asia. The world's swine and buffaloes populations are more or less confined to Asia (58%) and 97% respectively. The world poultry population is estimated to be 18 billion. Of the 24 million camels in the world today, most are found in Africa (84%). According to available estimates, livestock furnish between 25 - 50% of the world's total value of agricultural products (Brumby, 1987). Livestock probably constitute the most valuable asset of the rural population in Tropical Africa apart from land (Jahnke, 1982).

The role of livestock in developing countries extends beyond their traditional uses of supplying meat and milk as found in the industrialized countries (Sansoucy, 1994). Livestock are important sector of economies through the production of food (meat and milk), provision of security, enhancement of crop production and generation of cash incomes for rural and urban populations; provision of fuel and transport and production of value added goods which have multiplier effects and create a need for services. Livestock diversify production and income, provide year-round employment, spread risk and form a major capital reserve for farming households (Jahnke, 1982).

Livestock are, in addition, valued for capital, credit, traction, hides and fertilizer. For families, livestock are primarily means of increasing the family income. For the crop

farmer especially in Asia, Africa and Latin America, the large livestock (cattle and buffalo) are prime sources of traction and power. On the other hand, for the transhumant grazer, livestock may be the most valuable resource for capital or credit. Thus developing or improving production systems must take these varied roles into account and adapt them to fit into specific local situations (Preston, 1995). Livestock production in tropical countries has, as in the past, been one of the important economic and social activities of human culture. In these regions, hundreds of millions of people depend directly or indirectly on livestock-based activities (Preston, 1995)

According to White *et al*. (2000) the availability of land is a major factor in extensive livestock production. The resource, much like water, has been disappearing at an alarming rate since 1981. In order to cope up with food requirements of increasing world population, the pressure on natural resources is increasing. Degradation of this resource results in declines of productivity and biodiversity. This negative process accelerates the expansion of the global problem of desertification. An estimated 8 million hectares of farmland is replaced each year by homes, shopping centers, industries, and roads built to accommodate growing populations. The replacement is of course taking place at the expense of rangelands, which hitherto has only been used for grazing purposes. Since 1945, about 17 percent of the earth's vegetated surface or 2 billion hectares had been degraded or made less productive by human mismanagement. Poor agricultural practices that include overgrazing, plowing of vulnerable soils, over-fertilizing and irrigation without proper drainage have contributed to the degradation of about 552 million hectares of once productive grasslands (White *et al*., 2000).

The growing demand for livestock products will stimulate livestock production which, if well planned, can contribute to poverty alleviation (Thornton, 2010). In instances conversion of the most productive rangelands to cropland has often been accompanied by the concentration of larger number of livestock on smaller areas of marginal land (Sheehy, 1992). High numbers and poor distribution of livestock affect long-term ecological stability of grassland ecosystems. Environmental impact studies of existing grazing management strategies over wide areas of the tropics indicate that grassland ecosystems are being degraded. Data revealed soil loss from wind and water erosion, and declines in both grassland and livestock productivity (Sheehy, 1993).

There is a profound difference between proper and exploitative use of rangeland vegetation. The act of grazing is an evolutionary component of grassland ecosystems while overgrazing or over utilization is an act of human insensitivity (Conner *et al*, 1998). As important as livestock production is in the socio-economic well-being of the world's population, it is often given the least priority when it comes to resource allocation, especially land. It is usually allocated unproductive land that has no alternative use.

Sustainable grazing land management is imperative if production of livestock and associated products must keep pace with the increasing number of people. Creating adequate food supply poses two challenges: the first is to provide enough food, especially animal protein, to meet the needs of the expanding population without destroying natural resources needed to continue producing food; and the second is provision of food security that ensures people have access to enough food to live active

and healthy lives. The major concern of animal husbandry today is the extent to which these challenges could be met as the human population increases.

Overgrazing has been recognized as the primary deterrent to sustainable range livestock production (Ruyle, 2003). Research and experience indicate that ranges can be grazed at any time of year without serious detriment if the intensity of grazing is not too severe and if periods of grazing alternate with suitable periods of rest (Martin, 1975). This is the theory and philosophy of the sustainability of range livestock production – a concept which was variously referred to as "the amount of stock that these lands will carry profitably year after year" (Griffiths 1904), "keeping utilization in harmony with forage supply" (Roach 1950), "sustained use without deterioration of rangelands" (Reynolds 1954), and " providing relatively stable livestock production without seriously impairing other important resource values" (Martin and Reynolds 1973), among many others.

The assessment of livestock production parameters in extensive grazing systems in tropical developing countries indicated lower indices relative to intensive systems. Salazar and Torres (1981) reported that the average fertility rate rarely exceeds 50% and is often less; average stocking rates are less than one mature cattle unit per hectare; slaughter age for 450 kg live weight steers in more than 40 months; mortality rates frequently reach high figures in many regions due to contrasting food supply situations caused by long droughts and dry periods. The main factors responsible for these poor indices of production are the low quantity and the poor quality of the available biomass in open access land.

## 2.3 LIVESTOCK PRODUCTION SYSTEMS

There are many possible classifications of livestock production systems but they can be broadly classified into three: the extensive, the semi-intensive and the intensive systems (Steinfeld, 1998). In Africa a common classification uses the degree of movement as a descriptor as follows: nomadic, transhumant and sedentary systems (Wilson, 1995). Irrespective of system of classification, the year-round provision of feed and water is the main daily pre-occupation of the livestock producer. Similar to all biological entities, animals must be routinely and optimally fed and watered to yield products in the form of fertility/offspring, milk, meat, etc. Feeding and watering for that matter, account for over 80% of production costs in animal production.

### 2.3.1 Extensive Production System

The extensive production system is a resource-driven and labour-intensive sector providing a multitude of services to subsistence-oriented farms. It is the main production system in Africa and Asia. The system uses resources of little or no alternative uses for direct human consumption but converts them into high quality products. Its potential for expansion beyond moderate growth rates is constrained by low technology uptake, insufficient market facilities and infrastructure and small scale economies of production. Often, this system runs on closed cycles of nutrients, farm labour and energy (Steinfeld, 1998). Under this system, seasonal fluctuations in feed supply and quality are mainly buffered by the loss of weight of the animals which limits their productivity (Thomas *et al.* 1992; Seré *et al.*, 1995). Pasture improvements or supplementation play a limited role

in solving this bottleneck, because the economics of such practices are not attractive enough under the prevailing conditions (Thomas *et al.,* 1992).

Pastoralists have developed resilient grazing systems which maintain relatively high human populations on rangelands of low and highly variable productivity. They use a mixture of livestock species (cattle, sheep, goats and camels) and native breeds selected for adaptation to extensive mobility and the harsh environment. Small ruminants with their shorter generation interval and higher reproductive rate play a key role in building up stock populations after periodic droughts have destocked the system (Steinfeld, 1998).

Rangeland with its diversity of forage species is the overwhelming feed resource used in the extensive system of production. The variation in rainfall quantity and its seasonal distribution determines the availability of feed resources over time and space. Managing the production risk caused by the variability of feed availability is the central issue in the system. Pastoralists rely mainly in movement of stock across a diverse landscape, taking advantage of small patches of wetlands and the interface with cropping systems. The stocking rates are higher than those used by commercial ranchers under similar ecological conditions. Pastoralists have developed labor-intensive, input-extensive systems while ranchers use less labor, more capital and less efficient use of the land resources, to achieve higher productivity. Migratory herding based on extensive and frequent movement of livestock has declined in importance over most of Africa in the second half of the $20^{th}$ century. This is due to the reduction in the land area available for migratory herding, much of which had been taken up for other agricultural production activities, particularly modern plantations and wildlife reserves (Newman *et al*., 2007).

### 2.3.2 Semi-intensive System

Semi-intensive system is a kind of transition between extensive and intensive production systems. In this system, animals are grazed on pasture and crop residues, but are supplemented with by-products of grain processing and concentrate while manure generated is returned to the crop fields with the animals providing the draught power for land cultivation (de Leeuw *et al.*, 1999). This is what is commonly referred to as crop-livestock integration in developing countries (FAO, 2006). As a result of the ever-increasing pressure on land, the extensive livestock production system can no longer thrive as it did in the past because most of the land which served this purpose in the past has been converted to several other uses (Qureshi, 1993). Nomadism has very much reduced. Most of the nomads have become semi-sedentary and are practicing some arable cultivation alongside livestock production. It is under such circumstances that semi-intensive livestock production has emerged. Under this system, the livestock producer has a permanent home base from which he migrates to grazing sites when situations at his home base are unable to sustain his stock and only returns when feed situations improve (Mannetje, 1993). The pastoralist still grazes the rangeland, but also makes some contingency arrangements including on-farm crop residues conservation and provision or purchases of supplementary feeds like cereals bran, oil seed cakes and crop residues from other producers for his livestock (Aregheore, 2005).

### 2.3.3 Intensive Production System

This is demand-driven and capital intensive "high input, high output" production system which involves concentration of animals of single species into large units. The system is more often associated with poultry, pork and sometimes milk production enterprises which increasingly use state-of-the-art technologies (Steinfeld and Maki-Hokkonen, 1995; Nierenberg, 2005). It is rapidly expanding and meeting urban demands but is also susceptible to market upheavals. The system generates little employment while posing great environmental risks by creating a number of novel challenges for public human and veterinary health services. Intensification pays less attention to animal welfare and results in production of large volumes of waste material with implications on animal and human health risks (Preston, 1995; Bekoff and Meany, 1998; Munro, 2000; Singer, 2001). According to Delgado *et al.,* (1999), livestock production under industrial and intensive systems can cause major environmental problems and have been called "the most severe environmental challenge in the livestock sector". Examples are most found in northwestern Europe, the eastern and Midwestern United States and Japan (de Haan. *et al.,* 1996).

Several factors are responsible for the attainment of grassland agro-ecological system and environmental stability in the industrialized regions of the world. Among these are first, the creation of stable marketing and transport infrastructures that facilitate removal and sale of surplus animals, secondly, improved education of landholders in resource management and thirdly a rapid expansion of knowledge relative to proper grazing management. Other factors are accelerated communication systems and commitment by

governments to address overgrazing issues and the emergence of a strong land conservation ethics (Conner *et al*., 1998). Much of these developments are lacking in the developing regions. Environmental problems associated with livestock grazing have arisen because of institutional, non-agricultural interest groups who impose rules and laws that limit livestock grazing. This is exacerbated by increasing public ignorance of the impact of grazing which results in social and economic conditions that marginalize grazing-based holdings (Conner *et al*., 1998). Feed production requires land which continues to be the limiting factor to livestock sector's expansion. In the developed economies, most beef cattle are raised on large rangelands, but following weaning, the young animals to be used for meat may be fattened in feedlots, while dairy cattle are managed in relatively large herds under intensive conditions near centers of dense population (Robinson *et al*., 2011).

## 2.4 ROLE OF RANGELANDS IN LIVESTOCK PRODUCTION

Rangelands are used for the production of livestock and variety of wildlife. They serve as source of high quality clean water, clean air and open spaces which benefit people as a setting for recreation and economic activities of agriculture, mining and others. They produce forage for cattle, sheep and goat flocks, horses, water buffalo and numerous wildlife species. The harvesting of range forage, produced almost totally from solar energy, remains the most basic way to convert sunshine to food (Ruyle, 2003). In areas where the intensity of livestock production is low, such as the developing regions of Africa and parts of Asia, ranchers rely heavily on native grasslands for grazing and stock production without external inputs (Delgado *et al.*, 1999). In areas of high intensity of

livestock production, under industrial and intensive mixed farming systems, high concentrations of animals can cause major environmental problems (Delgado, *et al.,* 1999).

The development and application of the art and science of range management is necessary requisite for long term stability of the range livestock industry as an economic base (Ruyle, 2003). The productivity and efficiency of livestock production per animal unit are the key issues. Feed production, feed utilization, animal fertility, production and survival of offspring, calf survival and other productive traits need to be recorded systematically to monitor and evaluate productivity.

The biomass availability and the potential to produce more biomass in the tropical countries are many times higher than in the industrialized countries which are exclusively situated in temperate zones. However, the potential of tropical feed resources has just begun to be recognized. There is need to devise ways of exploiting them on a sustainable basis (Preston, 1995). This underscores the need for application of range management principles which focus on the integration of the soils, feed resources base and animal interfaces for animal production on a sustainable basis.

### 2.4.1 Effects of Grazing on Rangelands Productivity

Sustainable grazing management or land resource use is a key issue of concern in most arid and semi arid regions of the world. The World Commission on Environment and Development (WCED) defined sustainability as "ensuring that development meets the needs of the present without compromising the ability of future generations to meet their own needs" (The UN, 1987). Many complexities are involved in assessing the

sustainable use of tropical rangelands. At government level, decision makers face a problem of inadequate and inappropriate data. In many cases the data regarding the interactions of the different components of natural rangeland ecosystems may not be available due to deficiency in technical expertise (Umrani, 1998). This is one of the greatest limitations in rangeland development of the sub-Saharan Africa.

Plants vary greatly in palatability to livestock, and the preferred species tend to get grazed heavily, especially when animals are allowed to graze year round (Reynolds and Martin, 1968). Grazing can influence vegetation of the range, primarily through selective herbivory on plant species over time and space. General impacts of open range grazing and unrestricted livestock numbers were well documented in temperate regions at the turn of the century. We could learn and borrow from such data. These included loss of forage productivity and increases in plant species less palatable to livestock, bare ground, soil erosion and general land degradation. Overgrazing may arise from large herds of cattle harvesting forage beyond the production capacity of the vegetation. The consequences of land degradation translate into soil compaction, broken soil crust and erosion as well as reduced species diversity and density (Chamshama and Nduwayezu, 2002). The compaction of soil by animals and the removal of vegetation through defoliation may decrease water infiltration, increase soil erosion and decrease plant growth. In permanent grazing systems, there is little opportunity to ameliorate compacted soil through tillage.

Interactions between the soil, plants and animals within grazing systems make it difficult to separate the effects of treading from defoliation and excretal return (Sears, 1956).

Treading as a necessary process in grazing directly damages pasture foliage by mechanical action and fouling with soil, but can also indirectly affect pasture growth through deterioration of soil physical properties. It usually leads to changes in the botanical composition of pasture after a long time, especially when in combination with effects of selective grazing and adaptation of the pasture primary species to defoliation (Greenwood and McKenzie, 2001).

Technical interventions such as reseeding and fertilizer applications on degraded rangelands are constrained by risk of failure, communal ownership and large financial expense involved. As result, most users are unwilling to invest in range rehabilitation (Behnke and Scoones, 1993; Boyd and Svejcar, 2009). However, government policy can influence stakeholders in rangeland improvement directly through taxation on higher stocking rates, by providing improved veterinary services and insurance services for pastoralists who keep sustainable stocking rates. Indirectly they may be induced by improvement in road services, marketing facilities and extension facilities. Forage deficits can be alleviated by supplementation with external feed inputs or extending the grazing season by including legumes, forage herbs, shrubs and trees (Behnke and Scoones, 1993).

Rangelands, which are located not far from large cities, have the potential to become large animal production centres, to satisfy some of the needs for animal products of those cities. Range development techniques in such areas may encompass improved transport and communication services, convenient markets and provision of feed supplies. The latter assumes adequate supplies of agricultural and industrial by-products (cereal brans

and oil seed cakes) at reasonable and affordable prices which can encourage pastoral people to increase production through individual animals, rather than keeping large numbers of unproductive animals. In developing countries policies are generally based on political considerations and economical benefits, so strengthening the political representation of local pastoral communities will also transfer the benefits of development projects to local pastoral people (Scoones, 1995).

Rangeland-based livestock production usually keeps animals to exploit time and space variation in availability of herbage. The key grazing management strategy is to control stock numbers and also combine animal species with different forage preferences. Stocking densities are however made flexible in order to achieve sustainability of production. Twice number of animals than standard stocking rate are kept at maintenance level to achieve sustainability. At high stocking rate for production per hectare, feed availability is lower than that required for production per animal. This is what obtains in pastoral systems found in arid and semi-arid ecosystems and thus their productivity is most easily affected by climatic factors such as rainfall, rather than by animal numbers (Bayer, 1995).

Rainfall fluctuations from year to year in the tropical rangelands make it difficult to devise perfect stocking strategies and grazing management to cope with the variability. A fuller understanding of ecosystems function is necessary in developing sustainable grazing strategies in an attempt to restore degraded rangelands and maintain productivity. It is needful to understand the effect of plant competition on plant size and number of plant per unit area; the effect of defoliation on vigour, competitive ability, longevity and

production of individual plant species. There are also differences in the seasonal growth patterns of grass, legume and shrub species. This knowledge can be used for grasslands management to encourage the growth of one species at the expense of others. Also increasing grazing pressure on actively growing undesirable species will give a chance for desirable species to grow better.

As the option of moving livestock to new areas to relieve grazing stress during dry periods is increasingly becoming restricted in the developing countries due to increasing human population, animal production must adjust and adapt to smaller unit area of land. In production systems under constricted area, stocking rate becomes the determining factor for sustainability. The main factor influencing rangeland primary productivity is the kind and number of plant species present, number of plants per unit area, their longevity, palatability and resistance to grazing. In many rangelands of the tropics with large variations in rainfall from year to year, the stocking rates cannot be held constant. A conservative stocking rate can reduce the risks of degradation of rangelands and give better production per animal compared to higher stocking rates. Light stocking rates will be required to match average rainfall to reduce the risk of forage deficit, death of animals and financial losses in low and average rainfall years. A major challenge is to convince pastoral people about the benefits of reducing stock numbers and improving production efficiencies (Umrani, 1998).

### 2.4.2 Assessing Range Condition

Range condition is generally defined as departures from some conceived potential for a particular site (Holechek *et al.,* 2004). The assessment of range condition is a necessary

prerequisite for determination of whether to embark on range improvement or not. There are number of methods developed for assessing range condition and classification (West *et al*., 1994), but the one most commonly used is that developed by Dyksterhuis (1958, 1983). In this approach, range condition is measured in degrees of departure from climax. Generally, four condition classes are recognized: excellent (76 - 100% of climax), good (50 - 75% of climax), fair (26 - 49 % of climax) and poor (0 - 25% of climax). The classification provides an indication of management inputs necessary. Ehlert (1990) following similar classifications differed in terms of the degrees of departure from climax and proposed some indicators that can be used for assessing the range condition with recommendations. These criteria are defined in Table 1 and may need to be tested and verified against the conditions prevalent in tropical savanna environment. These indicators can be quite useful in assessing the condition of the rangelands in the savanna zones of Nigeria. Understanding the condition will determine the option for improvement either by introduction of new forage species and/or adjustment of management systems. However, while most of the rangelands in Nigeria can generally be classified as fair or poor, there are no empirical data to verify that because there has been no long term monitoring of the rangelands to record definite changes over time.

Table 1: Determination of range conditions and recommended actions

| Condition | Criteria |
|---|---|
| **Excellent** | 1). 75-100% of the potential yield for the area<br>2). 95% of the production coming from the desirable species |
| **Recommendation**: | Maintain management system |
| **Good** | 1). 60-75% of the potential yield for the area<br>2).75-94 of the production coming from the desirable species |
| **Recommendation:** | Maintain management system |
| **Fair** | 1). 50-60% of the potential yield for the area<br>2). 51-74% of the production coming from the desirable species |
| **Recommendation:** | Consider management changes and rejuvenation methods |
| **Poor** | 1). 33-55% of the potential yield for the area<br>2). Less than 50% of the production coming from the desirable species |
| **Recommendation:** | Introduce new forage species and adjust management system |

Source: G. Ehlert, 1990, Alberta Agriculture.

### 2.4.3 Range Rehabilitation Methods

The potential for range improvement will depend on factors related to edaphic and other natural environmental conditions, vegetation composition, location of the site, choice of technique employed, water availability and socio-economic condition of the developing institution (Ayuko, 1975). The main approach to development and improvement of natural grasslands may involve improvement of their management and utilization and/or introduction of suitable improved pasture species into the natural pasture. Legumes have been found to be very useful in this respect. Improved legume species are introduced into natural grasslands by over sowing or a combination of over sowing and improved management and utilization (Kusekwa and Lugenja, 1983; Lwoga, 1983, Kusekwa *et al*., 1990).

The improvement of natural rangelands usually requires some means of bush eradication and reseeding. In any case, there is necessity of adequate grazing management practices which include periodic rests from grazing during critical growth periods (Crowder and Chheda, 1982). Successful establishment of grasses and legumes sown into natural and semi-natural grazing lands lies in the choice of appropriate species, application of suitable techniques of land treatment, use of fertilizers, especially phosphate and appropriate methods of sowing.

The productivity of a forage field depends upon many factors including available moisture and nutrients and the presence of productive forage species. Loss of production may be due to weather, decline in fertility, and poor management. While it may not be possible to influence weather, there are options to correct some of the other causes. For

pastures that consist primarily of native species, adjusting the grazing management is perhaps adequate to encourage the growth and development of the more productive forage species. This will, however, require time for the more productive species to return to the pasture. Thus there is more interest in introducing new, more productive forage species into the pasture system than waiting for natural plant succession to the more productive species. Seeding more productive and adapted native species into an existing native stands is quite successful in improving productivity (Stewart, 2004). Perhaps the most important practice to improve the productivity of a pasture land is to use a management system that allows the productive forages to rest and recover following a grazing period. Grassland technical interventions include among others reseeding, fertilizer application, bush clearing and grazing management. Short time forage limitations can be alleviated by supplementation with external feed inputs or extending the grazing season by including legumes, forage herbs, shrubs and trees (Stewart, 2004). However, in developing overgrazed degraded rangeland, rehabilitation and reseeding is to trigger a biological revival and a plant re-colonization process. It is invariably a costly exercise which requires weed control and soil fertility treatments in combination with protection from excessive grazing especially at the initial stages of establishment. The rehabilitation process is of various forms depending on the range condition class in respect of the degree of range deterioration.

#### *2.4.3.1 Complete Renovation*

One of the most effective ways of improving forage production is the complete cultivation or renovation of the existing pasture to establish a new forage stand by sowing seeds or transplanting of vegetative splits. This is usually an expensive option and in some soils, where erosion or other environmental stresses are of concern, may have to be approached with caution. It is usually the accepted method where forages are used in a crop rotation. Some of the management highlights of this method are: destruction of existing forage species by the use of an herbicide and/or cultivation to minimize competition for the emerging forage seedlings; developing firm, even seedbed to encourage seed germination and plant establishment; use of seeding system that will ensure placing the small forage seeds shallow for maximum emergence, application of appropriate fertilizer to correct any nutrient imbalances and employment of minimum operations to enhance seed placement with minimal soil disturbance. An environment is provided to allow the emerging forage seedlings to establish successfully.

#### *2.4.3.2 Use of Companion Crops*

Companion crops are also known as cover crops or nurse crops. The practice involves the establishment of pastures with short-term crops usually in alternating rows. This has been practiced for a long time (Skerman *et al.*, 1988). In this practice, annual crops are inter-seeded with perennial pasture plantings to prevent soil erosion, suppress weeds and for the production of useable crop in the year of establishment of the forages (Manitoba Forage Council, 2006). The practice is more successful in areas that have adequate growing season precipitation. Generally, the best companion crops are small grain crops seeded at half or less than half the normal seeding rate. Companion crops that are

competitive for nutrients and moisture are not recommended on sandy soils or under dry land conditions. The system could also be the sowing of grasses into tall crops such as maize, sorghum and millet.

Several studies have shown the advantages and use of companion crops in establishing new pastures. Haggar (1961) obtained successful establishment of *Andropogon gayanus* with use of maize and soyabean as companion crop in northern Nigeria but *Stilozobium* spp and *Pennisetum pedicellatum* were found to be too competitive to allow for *A. gayanus* establishment. Rains (1967) undersowed *Chloris gayana* into millet (*Pennisetum americanum)* and obtained good cover of the grass at the time of millet harvest. Similar results had been found in Kenya with *C. gayana* and maize (Golden, 1967), in Colombia with *Panicum maximum, H. rufa*, and *Digitaria decumbens* sown into maize (ICA, 1973) and in Malawi *C. gayana* and *Desmodium uncinatum* sown into maize (Thomas and Bennett, 1975). The Sukuma agropastoral community used their indigenous silvopasture companion crop technology known as *ngitiri* to alleviate the dry season fodder supply shortages, conserve and protect soils and reclaim degraded land (Kilahama, 1994 a,b; Maro, 1995; Msangi, 1995; Kamwenda, 1999).

#### *2.4.3.3. Sole Crop Seeding*

Sole crop or mono crop is the production of a single crop without mixture of any kind. In sown pastures, sole cropping is mostly seen as sole grass or sole legume pastures. This is mostly found where seed production is the motive for establishment of the sward; otherwise, a combination of different species is more often used in grazing, hay or silage crop production.

### *2.4.3.4 Grass-Legume Mixtures*

Grasses are usually the predominant species in sown pastures and grazing lands because of their greater aggressiveness, stronger competition for nutrients and higher resistance to intensive grazing, trampling by animals and burning as compared to legumes. Tropical grasses which form the main forage resource in tropical rangelands are noted to be inherently low in crude protein concentration and high in crude fibre content. The resultant effects are reduced voluntary intake and animal performance culminating into low production levels or costly supplemental feeding (Milford and Minson, 1965; Minson and Milford, 1967).

An alternative option has been the incorporation of legumes into grassland systems. There are advantages for striving to maintain legume-grass mixtures in the sward available for grazing; which include improved soil fertility and productivity of most forage yields and nutritional status of ruminants above that obtained with grass alone (Crowder and Chheda, 1982). This is achieved in ways that influence the soil-plant-animal interface. There is increase in amount of crude protein available in the legumes for the grazing animal as the grasses begin to mature earlier during the dry season with high lignification. The grazing period is usually extended into the dry season by legume inclusion because many legumes remain green throughout much of the dry period at a time the grasses are brown and the nutritive values of the legumes remain at a higher level. Additionally, the legume fix N for the companion grasses thereby enhancing their yield and nutrient content. It is estimated that legume can provide up to 100 - 200 kg N /ha or more on an annual basis (Crowder and Chheda, 1982).

In low-protein forage-based diets (i.e., less than 7% crude protein) the supplementary effect of legume addition has been to overcome N deficiency in the forage by providing ruminally degradable protein (McLeod and Minson, 1969; Paterson *et al*. 1981; Brandt and Klopfenstein, 1986). In high protein diets (i.e., greater than 10% crude protein) response to legume addition has been similar to that obtained from slowly degraded proteins which escape ruminal degradation (Flores *et al*., 1979). In agricultural ecosystems, the integration of legume species can produce synergistic effects and minimize external inputs, especially nitrogen fertilizers (Thomas and Sumberg, 1995; Peters *et al*., 2001).

Biological N fixation may be regarded as one means of increased net primary productivity directed to increasing carbon sequestration. Thus legumes may also contribute in mitigating global warming through increased net primary productivity, improved diet quality, and reduction of methane emissions from cattle. Legumes are important in the maintenance of the nutritive value of forage, both when they are ingested directly or where they contribute N to minimize the expected reduction in leaf:stem ratio and the protein dilution in the associated grass as $CO_2$ level increases (Humphreys, 1997; Valentim and de Andrade, 2004).

#### *2.4.3.5 Grass-Legume Rotations*

Including forages in crop rotations is one of the alternative means of improving soil quality. Crop rotations, in general, reduce input costs and lower financial risk. Of fundamental importance in crop rotation is the enhancement of soil organic matter and soil structure. The root structure of forages is finer, so they break down more easily

allowing air and water to enter the soil with ease. Also as forages break down, they produce binding products that act like glue to hold the soil together. The net result is larger and more stable soil aggregates that are better able to resist wind and water erosion (Sullivan, 2003).

One drawback of including forages into crop rotation system is the problem associated with termination of the forage stand from arable land. Producers tend not to use forages in their rotations because termination requires complete tillage. This usually involves time intensive and expensive field operations which use large amounts of fossil fuel. Tillage practices can also result in soil drying and crusting which reduces many of the soil improvement benefits of the forage. Thus the use of herbicides is recommended as a less expensive and tedious approach which may help in the termination of forage stands (SSCA, 2003).

#### *2.4.3.6 Under-sowing or Sod Seeding*

This is a practice used to introduce a more productive forage species into an existing forage stand. It is also known as sod seeding (Barnhart, 2004). It is often used especially on sites having limitations to cultivation by stones, brush or soil erosion problems. Legumes have generally been most successful for sod seeding although there are a number of grass species that will establish reasonably well. Legumes are usually preferred as they reduce the need for nitrogen application and will improve the quality of the forage (Nazarko and Winnipeg, 2008). In most cases equipment used for sod seeding must be able to penetrate the sod layer (thatch layer) and place the seed into the mineral soil. Depth control is required so that the seed is not buried too deep to restrict

emergence. A packer wheel is used to close the slot to reduce drying out of the soil (Bowes, 1997).

Under-sowing is a challenging experience as the seedling is usually placed into a very hostile and competitive environment. There is competition from the existing forage and other plants, and there are also insects that love the freshly germinated seedlings. To reduce the competition from other plants, use of a non-selective herbicide such as Roundup® (glyphosate) applied one to two days prior to seeding is a common practice (Bowes, 1997). The forage to be controlled needs to be actively growing for the herbicide to be effective. Other systems used to suppress old stands are:

(a) Close grazing to weaken the existing plants enough and provide advantage to the new emerging forage seedlings,

(b) Close cutting (mechanical) of the existing stand, and

(c) Controlled burning to burn off old growth that could interfere with the seeding process (Nazarko and Winnipeg, 2008).

#### *2.4.3.7 Over Sowing*

Over sowing involves the broadcasting of seed into natural or native grasslands. The cost of this process is usually quite low, but due to lower seed germination and establishment, the amount of improvement achieved may be quite limited, in comparison to other options. However, this method of range improvement or rehabilitation has been used with some levels of success in Nigeria (Foster, 1961; Haggar *et al*., 1971) and Australia (Downes, 1967; Gillard, 1977; McKeague *et al*., 1978).

#### *2.4.3.8 Livestock Seeding*

The method involves feeding forage seed to the animals with expectations that the seed is deposited on the pasture through the manure. Crowder and Chheda (1982) considered this as an extravagant use of seed with uneven distribution. There are obvious limitations with the method which are: (a) that the animals may digest the seed while passing through the gut so that the amount of live seed in the manure may be very low, (b) the ammonia in the manure can also have an effect on the germination and (c) there is minimal control of where the cows will deposit the manure (and hence the seeds).

#### *2.4.3.9 Strip Seeding*

The planting or sowing of forage and fodder crops in narrow belts or strips in active grazing lands have been suggested as a means of improving the pasture and providing supplemental feed for grazing animals (Crowder and Chheda, 1982). In Queensland, Australia, strip planting of Townsville Stylo (*S. hamata* cv Townsville) into native grasslands increased herbage available for grazing, as well as the stocking capacity, and facilitated the spread of the legume into non-seeded areas by seeds passing through the grazing cattle (Graham, 1968). This method has been tested at Runka Grazing Reserve with *Andropogon gayanus*, *Pennisetum pedicellatum* and *Stylosanthes hamata* strips under the National Livestock Projects Department (NLPD) model Grazing Reserve development (Kallah, 2009 Unpublished).

#### *2.4.3.10 Spot Seeding*

Spot seeding is simply dropping a predetermined number of seeds on a small spot by hand in a lightly cultivated spot (Morgan and Rickson, 1995; Barnett and Baker, 1991) as

opposed to cultivating the whole area to be planted. The method is widely used for filling patches of bare ground in larger pasture fields. It is very slow and labour intensive. The seeds will usually germinate in clusters and therefore should be thinned to the recommended stands per spot to reduce competition. Spot seeding is most appropriate for difficult terrains such as steep slopes which are prone to erosion, or rocky soils which would not permit cultivation. Spot seeding is also adopted when seed is in short supply or when overall seeding is impracticable. Spots of different species can be mixed in the required proportion in the same way as for planted species. Seed spots can also be successfully used to introduce new species into an established vegetation cover, such as a sward (Morgan and Rickson, 1995).

## 2.5 ROLE OF LEGUMES IN PASTURE SYSTEMS

Tropical pastures generally have high photosynthetic capacity and thus have the potential to produce large quantities of biomass. However, both the quantity and quality of the biomass changes during the year and over time, depending on the length of the dry season and soil fertility of the location. In areas of long dry season, live weight gain and milk yield can be severely depressed on pastures based on grass alone. An alternative to minimize declines in quantity and quality of forage biomass and thus increase livestock production is to utilize legumes in pastures (Lascano, 2000). The establishment and maintenance of persistent grass-legume pastures is one of the options to increase productivity, profitability and also to ensure long-term sustainability of cattle production systems in the tropics (Valentim and de Andrade, 2004).

Legumes are desirable components of pastures and grazinglands where nitrogen is a limiting factor for optimal growth of associated grasses, or where a need exists for increased crude protein in herbage available for grazing, or where extended grazing into the dry season is desired or when stability of the pasture system is given high priority (Crowder and Chheda, 1982). One of the very desirable characteristics of most forage legumes is that they remain green when grasses mature and become dry with the onset of the dry season.

Legumes are grown on some 180 million ha, or 12% to 15% of the Earth's arable surface and rank second to Gramineae in their importance to humans (Graham and Vance, 2000.). Both grain and forage legumes account for 27% of the world's primary crop production, with grain legumes alone contributing 33% of the dietary protein nitrogen (N) needs of humans (Vance *et al.*, 2000). Forage legumes are integral components of sustainable agricultural systems, providing high quality livestock feed, nectar, seed, green manure, and soil cover.

Forage legumes are multipurpose plants which can increase resource and land use efficiency in cattle production systems by:

1) increased forage yield and quality especially during the dry season
2) improving weed suppression, pest and disease reduction as a result of increased ground cover and ecosystem diversification
3) adding N to the system through symbiotic nitrogen fixation and
4) improving nutrient cycling (Valentim and de Andrades, 2004; Humphreys, 1994; Delgado *et al.*, 1999; Peters *et al.*, 2001).

According to Russelle (2001), forage legumes have been the foundation for dairy and meat production for centuries. When properly managed, they are rich sources of protein, fiber, and energy. Even in intensive animal and milk production, where grain crops are major feed sources, forage legumes are required to maintain animal health (Wattiaux and Howard, 2001). Legumes are critical for sustainable meat and dairy production on the infertile savannah soils of the tropics and subtropics. Species from the genera *Aeschynomene*, *Arachis*, *Centrosema*, *Desmodium*, *Macroptilium* and *Stylosanthes* offer promise for improved tropical pasture systems (Thomas and Sumberg, 1995; Giller, 2001). *Stylosanthes* spp. with some 30 species distributed throughout the tropics has been most widely adopted, with *Stylosanthes guianensis* and *Stylosanthes hamata* now grown as improved pasture in Australia, China, Latin America, and West Africa (de Leeuw *et al*., 1994).

Research in grass-legume pastures in Africa has been mainly conducted in Uganda, Nigeria and Zimbabwe. Pasture research in Nigeria focused attention on improving dry season nutrition using legumes. Most work was carried out in the genus *Stylosanthes.* Three species, namely *S. guianensis* cvs Cook and Schofield, *S. hamata* cv. Verano and *S. humilis* have received most research attention (Agishi and de Leeuw, 1986). The effect of legume–grass associations can be expressed in terms of dry matter yields, N content of herbage, yield of protein, animal intake of forage and animal productivity. Results from such works showed that animal production can reach approximately 140 - 155 kg/hd/year and production/unit area 525 - 650kg/ha/year on grass-legume pastures in the pastures (Agishi and de Leeuw, 1986).

### 2.5.1 Soil Fertility Management

Low soil fertility is one of the most critical limiting factors for agricultural production in the tropics with nitrogen being the most limiting nutrient in many agricultural ecosystems (Wedin, 1996; Humphreys, 1997). The main reason for this is that, even though the nitrogen (N) pool is the largest, it is available to plants only through highly endergonic biological processes mediated by free-living or plant-associated bacteria that require between 25 to 30 moles of ATP per mole of $N_2$ fixed (Marschner, 1995).

Oxisols and Ultisols are the predominant soil types of the tropics. These soils are of low fertility because they are highly weathered, well drained and acidic with low base status and available P (Baligar and Bennett, 1986). In areas where such soils are prevalent, cultivation of leguminous plants provides an economical means of adding nitrogen to the soil-plant-animal system (Crowder and Chheda 1982). The amount of nitrogen added to the soil is dependent on the legume herbage yield (Edman and Means, 1962; Jones, 1972). Recent studies in Brazil reported annual biological nitrogen fixation ranging from 88 to 180 kg/ha by three cultivars of *Stylosanthes* (Miranda *et al*., 1999) and 26 to 99 kg/ha by seven accessions of *Arachis* (Miranda, 2003).

Pastures are subjected to frequent harvests with increased nutrient removal resulting in declines of soil fertility and biomass productivity over successive grazing/harvesting rotations (Gonçalves *et al.,* 1997). The use of legumes in a forage mixture will improve the soil fertility and the productivity of most forage fields. Grass/legume pasture mixtures that have at least 50% legume content are usually fertilized with phosphate fertilizer as this nutrient encourages the growth of the legume.

### 2.5.2 Tool in Pest Control and Management

One of the unique features of forages is their ability to suppress weeds. The competitive nature of forages for light and nutrients, and the frequent cutting as hay reduces the vigour of weeds and their ability to produce seed. Adding forages to rotations help break pests and disease cycles. Crop rotation can minimize the amount of disease residue and soil-borne pathogens as disease pressures change with changing environmental conditions. Thus crop rotation, in conjunction with direct seeding and fungicides, is an effective method of disease control.

### 2.5.3 Forage Production

The presence of productive forage species in pasture ecosystem is a significant factor in determining the productivity of the forage field. Choice of species and combination need critical consideration. In grass-legume mixed pastures, dry matter yields quite often are higher per unit area than either sole grass or sole legume pasture (Asare, 1974; Skerman, 1977). Yields vary widely, depending on such factors as species of grasses and legumes, inherent soil fertility, fertilization (amount and time of application), percentage of legume, available soil moisture, intensity of defoliation, light intensity and temperature (Crowder and Chheda, 1982). The biomass availability and the potential to produce more biomass are quite often high in the tropics (Preston, 1995).

### 2.5.4 Nutritive or Feeding Value

An outstanding feature of the herbage available for grazing in a legume-grass mixture is the increase in N content as compared to grass alone and the constancy of N found in the legume component. Legumes contain higher amounts of N than grasses whether grown

alone or in mixture (Crowder and Chheda, 1982). The N content in legumes like *Leucaena leucocephala* may exceed 4%, while heavily fertilized grass seldom exceed 2.75% N in the juvenile herbage (NAS, 1977). Jones (1972) in Queensland, Australia found only very small changes in N content of *Macroptilium atropurpureum* (4.63 to 4.12 %N) over a period of 5 and 4 months. Tanko (1994) in Nigeria found N content of grass falling from 1.5% in the early rainy season herbage to 0.7% in the early dry season herbage.

Forage legumes have higher nutritive value than grasses: they are more digestible and higher in protein, calcium, phosphorus, and magnesium. This leads to higher voluntary intake of legume-grass forage than grass alone. Consequently, livestock performance is greater on pastures containing forage legumes than all grass. Over seeding legumes on perennial grasses results in extension of the grazing season thereby reducing costs and labor associated with dry season feeding.

### 2.5.5 Animal Production

The ultimate function of a pasture is animal production. The main products from animals are meat, milk and reproduction of the young. In most open access rangeland, optimal performance of animals is potentially limited by both the quantity and quality of the pasture being grazed. Improvements in dry matter yields and animal performance on native pastures augmented by legumes have been reported with significant implications on animal health and production parameters as well as improved calf crop (Edye and Gillard, 1985; Crowder and Chheda, 1982).

#### *2.5.5.1 Animal health interactions*

Certain legumes contain compounds that are potentially toxic to livestock, examples of which include mimosine found in *Leucaena leucocephala* (Borthakur and Soedarjo, 1999), tannins found in other legume species like *Calliandra grandiflora* and *Flemingia macrophylla* (Rosales, 1999), oestrogens in temperate legumes like *Trifolium pretense* and *Medicago sativa* (Marley *et al.,* 2011) and indospicine in *Indigofera spicata* (Gardener and Riet-Correa, 2011). Mimosine has been found to cause loss of hair in cattle and wool in sheep, breeding problems in swine and horses, enlarged thyroid glands, depressed liveweight gain in cattle and implicated in calf mortality (NAS, 1977). The presence of tannins in some tropical legumes adversely affects voluntary intake and digestibility of such legumes (Marshall *et al*., 1979). Bloat is one of the problems associated with fresh legume forages. It is, however, uncommon in the tropics because of the low soluble protein content and the presence of precipitating agents in tropical legumes (Jones and Lyttleton, 1971).

Oestrogens appear to interfere with reproduction, but tropical legumes do not contain sufficient amounts to be potentially dangerous (Bindon and Lamond, 1966; Little, 1969). Indospicine causes liver damage which restricts the use of legume species containing this substance in pasture improvement practices (Hegarty and Pound, 1968). Due to these health factors associated with some of the legume species, care must be taken in the choice of species for pasture development to avoid their deleterious effects on animal performance.

### *2.5.5.2 Liveweight Changes*

Cattle grazing grass-legume pastures have been reported to gain more body weight than those on grasses alone (Lopez *et al*., 2000). In southeast Queensland Australia, Evans (1970) found that at a stocking rate of 2.47 TLU/ha, the animals made mean annual liveweight gains of 290, 336 and 545kg/ha with average pasture legume contents of 13, 20 and 35% respectively. van Keuren and Hoveland (1985) also reported that lambs grazing legumes alone or grass-legume mixtures generally gained better than those grazing grasses alone. Supplementing *Cynodon nlemfuensis* with a two-hour browsing of a legume shrub bank yielded 20% higher liveweight gain than those on the grass alone (Ibrahim *et al.*, 2000).

There are several reports in the literature on higher liveweight gains obtained from grass-legume pastures compared to sole grass pastures. Examples include those from Uganda (Stobbs, 1965), Queensland (Grof and Harding, 1970; Gillard *et al.*, 1980), Peru (Santherasegaram, 1975). The difference in liveweight gain between mixed pastures and sole grasses ranged between 60 kg/ha in Uganda and 399 kg/ha in Peru (Stobbs, 1965; Santherasegaram, 1975). Studies by Vilela *et al.* (1999) in the Cerrados of Minas Gerais, Brazil, showed a 56% increase in live weight gain of Nelore heifers when degraded pastures of *B. decumbens* and *B. ruziziensis* were reclaimed using *S. guianensis* cv. Mineirão. In the Cerrados of Mato Grosso do Sul, Brazil, grass-legume pastures consisting of *B. decumbens* associated with *S. capitata* + *S. macrocephala* cv. Campo Grande resulted in 7%, 18% and 20% increase in animal live weight gain per hectare, when grazed under stocking rates of 0.6, 1.0 and 1.4 animal units/ha, respectively, in comparison with grass-only pastures (Valle *et al*., 2001).

Evidence from experimental results suggests that N supply is the main factor affecting animal production in a pasture-animal system. It was noted that the N content of grass in a mixture with legumes is less than 1% until the legume fraction exceeds 40 %. It was therefore concluded that the legume component in a mixture should be maintained at 30 - 40% in order to obtain optimum animal production (Crowder and Chheda, 1982).

#### *2.5.5.3 Milk Yield*

Luck and Douglas (1966) and Hamilton *et al*. (1970) reported some marginal increase in milk production from cows on grass-legume mixtures over those on grass alone. Dairy cattle grazing grass pasture but with a two hour access to a legume protein bank produced one liter of milk higher than those on grass alone (Ibrahim *et al.,* 2000). Lascano (1993). Cook *et al*. (2005) and Rivas and Holmann (2000) have reported a rise in milk yield of between 17% - 31% in mixed *Arachis pintoi*-grass pasture over grass alone in Colombia and Costa Rica. Lascano *et al.* (2002) compared the milk yields of lactating cows grazing *B. decumbens,* with those of cows grazing a pasture of the same grass planted with strips of *Cratylia argentea,* or grass-only pastures supplemented with the legume in a cut and carry system. During the dry season, milk production increased by 23% in cows grazing the grass-legume pasture in comparison with those grazing grass-only pasture, and by 12% in comparison with those grazing the grass-only pasture and receiving supplementation with the legume in a cut and carry system. Similarly, in the study at Minas Gerais, Brazil, milk production of cows grazing *B. decumbens and S. guianensis* cv. Mineirão pastures increased by 15.6% above those grazing sole grass pasture (Barcellos and Vilela, 1999 cited by Valentim and de Andrade, 2004).

#### *2.5.5.4 Reproduction*

Some evidence exists suggesting that legume component in pasture systems not only enhances liveweight gain but also increases conception rate of cows and decreases calf mortality. Cows on grass-legume mixtures had higher conception rates, calving percentage and weaning percentage than the cows on grass alone pastures (Koger *et al.* 1961, Warnick *et al.,* 1965; Guyton, *et al.,* 1980). The application of superphosphate to legume based pastures further increased the reproductive performance and beef production of animals grazing them. Edye *et al.* (1972) and Rural Research (1973) reported conception rate of 66% only by animals grazing unfertilized stylo and spear grass pasture, but when the pasture was fertilized with 110 kg SSP/ha the conception rate rose to 74% and at 330 kg SSP/ha up to 85%.

## 2.6 LEGUME UTILIZATION IN RANGE DEVELOPMENT

A wide variety of legume species have been identified as suitable for forage production under different systems. The underlying factors guiding the choice of species for use include adaptation to the environment, dry matter yields and persistence. For rangeland improvement, the ability of the legume species to compete favorably with the native vegetation, withstand grazing and fire are important factors to consider. This is more so in the rangelands of tropical Africa where uncontrolled grazing and yearly bush fires are the norm. Such legumes would need to be able to regenerate from old stumps or from seed and have to produce large quantities of seed. Grass-legume mixtures are viable and persistent option in pastures that are occasionally burnt (Reátegui *et al.*, 1995).

### 2.6.1 Forage Legumes Introduction in the Savanna

Agishi (1985b) reported that pasture legumes were first introduced into Nigeria in the 1940s, but it was not until 1956 that large-scale introductions were made at Shika and Ibadan. According to the report, the Shika Grassland Research Station (now National Animal Production Research Institute (NAPRI)) was the main centre for pasture introduction and evaluations. Between 1956 and 1977 over 700 entries of 97 legume species were made in Shika, of which 54 species were found to be adapted to the different ecological zones of the Nigerian savanna and 18 species were recommended for large-scale use (Agishi, 1979). Among the promising legume introductions were *Stylosanthes hamata* cv Verano, *Centrosema pascuorum* and *Chamaecrista rotundifolia* ( Agishi and de Leeuw, 1986; de Leeuw *et al*., 1994; Tarawali, 1994; Peters *et al*. 1994; Tarawali and Peters, 1996). These herbaceous legumes have been found to perform satisfactorily in the different ecological zones of Nigeria and constitute the test material for this study.

#### *2.6.1.1 Stylosanthes hamata (S. hamata)* ( L) Taub cv. Verano (Common name: Carribean Stylo)

*Stylosanthes hamata* is an annual to short-lived much-branched herbaceous perennial. It is semi-erect about 30 - 75 cm high, sometimes prostrate with fine green stems differing from *S. humilis* in having only fine white hairs down one side, but no bristles as in *S .humilis*. The plant produces 270,000 seeds-in-pod and 450,000 dehulled seeds/kg (Stace and Edye, 1984; Skerman *et al*. 1988, Edye and Topark-Ngarm, 1992; Cook *et al.*, 2005). *Stylosanthes hamata* is reputed to be the most drought-resistant species of the stylos with high adaptation to low fertility, acid soils

persistence in pastures and extreme tolerance to grazing and fire (Hanson and Heering, 1994). It has a wide range of moisture requirement with the optimum production in areas with 700 – 900 mm rainfall. It has, however, been found growing in areas with annual rainfall as low as 300 mm, and in areas receiving up to 2000 mm annual rainfall. In areas with long dry season the species behaves like an annual (Stace and Edye, 1984). It has shown tolerance to anthracnose and is rhizobially promiscuous and spread readily and widely by its hooked upper seed pod (Skerman *et al*., 1988).

*S. hamata* is mostly used for permanent pastures. It is good for cut-and-carry green feed, *in situ* grazing or hay if cut before dry season leaf fall when plants become increasingly stemmy. It can also be used in ley cropping systems with nitrogen benefits of up to 90 kg/ha (Pengelly *et al.*, 2004). It is palatable and used in feeding cattle, goat, sheep, pigs, and poultry. It has also been found useful in silvopastoral systems in India where it has been undersown in *Eucalyptus* and *Dalbergia* forests as a component in watershed and soil conservation programs (Chaisang *et al*., 2004).

*S. hamata* tolerates heavy grazing and the grazed plants tend to perennate better than ungrazed plants. Higher yields can be obtained from commencement of grazing at early flowering and then at 4-weeks intervals, compared to starting later and grazing less frequently. Under heavy grazing it can become dominant at the expense of perennial grasses. Grass and 'Verano' mixture can be maintained by strategic fire and grazing management with appropriate phosphorus fertilizer use on infertile acid tropical soils (Stace and Edye, 1984).

Studies indicate that *S. hamata* is palatable and nutritious with no record of toxicity (Hall and Glatzle, 2004; Chaisang *et al*., 2004). The nutritive value of leaf crop declines rapidly with the onset of dry season. Crude protein levels range from 17 - 24% in green leaf and 6 -12 % in the stem, and decline with age of growth and general growing conditions. P levels depending on the soil P status and age of regrowth vary between 0.08 - 0.3% of DM in green leaf and 0.06 - 0.34% in stems. IVDMD varies from for whole tops comprise of 66 - 72% for green leaf and 33 - 57% for stems (Hall and Glatzle, 2004).

#### *2.6.1.2 Chamaecrista rotundifolia (C. rotundifolia)* (Pers) Greene cv Wynn (Common name: Round-Leaf Cassia, Wynn Cassia)

*Chamecrista rotundifolia* is a short-lived perennial or self-regenerating annual herb, subwoody, semi-erect, growing to 1 m tall, with shallow taproot. Stems are pubescent to subglabrous, 45 - 110 cm long. Leaves are bifoliolate and the seeds rectangular and flattened, 2 - 3 mm long. There are 200,000 - 470,000 seeds/kg of *C. rotundifolia*. The cultivar, Wynn, has broad leaflets, 15 - 22 mm wide; long pods, 38 - 40 mm long; and small seeds (253,000/kg) (Cook *et al.,* 2005).

*Chamaecrista rotundifolia* is native to Mexico, South America and the Carribean, but has naturalized in West Africa and the U.S.A. (Strickland *et al*., 1985, Cook *et al*., 2005). It is sown into native pastures to augment feed quality and occasionally sown into pastures of improved grasses. It has limited value for conservation or standing hay because of substantial leaf drop under dry conditions, leaving woody indigestible stems. *C. rotundifolia* has been successfully used in cut-and-carry systems in Southern China. In Nigeria it had been used as a ley or phase legume in crop-

livestock systems with improved results in cereal production (Tarawali, 1994; Tarawali, 1995; Tarawali and Peters, 1996). It is one of the best adapted legumes on sandy soils in semi-arid northern South Africa and in semi-arid West Africa. *C. rotundifolia* behaves as a perennial under 900 - 1,500 mm rainfall and as an annual at 600 mm. It is reasonably drought-tolerant and is well adapted to free-draining light soils of low to moderate fertile red acid soils (Pengelly *et al.*1997). Plants tolerate poor drainage or flooding (Tarawali, 1994). Under heavier grazing, plants form rosettes. Leaves often turn red and drop if plants are left ungrazed (Jones, 1992; Pengelly *et al*., 1997). It is reported to be tolerant of constant heavy grazing (Patridge and Wright, 1992). Other favorable attributes of the species include its ability to combine well with native tussock and also open creeping naturalized grasses while spreading naturally through heavy seed set and lack of serious pests or diseases.

#### *2.6.1.3 Centrosema pascuorum (C. pascuorum)* Mart. ex Benth (Common name: Centurion, Pascuorum)

*Centrosema pascuorum* is an annual, twining herb that can root from the nodes of trailing stems under moist conditions. Stems are cylindrical, glabrous or scarcely pilose, extending up to 2 m from the crown. Leaves are trifoliate, often held erect and paraheliotropic especially during dry periods. Leaflets are 50 - 100 mm long and 5 - 10 mm wide which gives a *C. pascuorum* sward, from some distance, a grass-like aspect. Pods are linear to slightly curved, 4 - 8 cm long and 3 - 4 mm wide, laterally compressed with a dark longitudinal stripe. They contain up to 15 seeds and shatter violently at maturity up to one meter wide thus allowing self dispersal of seeds. Seeds are ovoid to cylindrical, approximately 4 mm long, greenish-yellow to brown and

rarely mottled. Thousand seed weight of *C. pascuorum* ranges from 6.8 - 28.9 g (Schultze-Kraft and Clements, 1990; Cook *et al*., 2005)

*C. pascourum* is a tropical lowland species, found naturally at altitudes between 20 m and 1,000 m. Its geographical distribution spans from almost $17^{o}$ N in Mexico to almost $20^{o}$ S in Brazil. Main areas of distribution are semi-arid northeast Brazil, the Pantanal, coastal Ecuador, northern Venezuela and Guyana, and Mesoamerica from southern Mexico to Panama. It is most commonly found in northeast Brazil and Venezuela. Annual rainfall at sites of origin is between 350 and 1,500 mm with 4 - 10 dry months. Soils at the collection sites are mostly of medium to high fertility (Ludlow *et al*., 1983; Clements, 1992; Cook *et al*., 2005). *C. pascuorum* is adapted to a wide range of soils, from sand to heavy clay and from slightly acid to alkaline soils (pH 5 - 8.5). Although occasionally found at sites with some seasonal flooding stress, *C. pascuorum* can adapt to tropical areas with pronounced dry season of up to 8 months. It performs optimally in areas having 700 - 1,500 mm rainfall per year. Morphological (i.e., the narrow leaflets), phototropic (i.e. erect leaves oriented towards sunlight), osmotic and stomata responses are adaptation mechanisms which confer it with drought tolerance.

*C. pascuorum* is suitable for mixtures with grasses or in pure stands in ley-farming (McCown *et al*., 1985; 1986). In ley farming, *C. pascuorum* stands persist through a seed bank and makes excellent hay. For hay production, renovation every 3 or 4 years is required to maintain a pure stand. It has moderate tolerance to grazing and cutting, giving high quality forage with good palatability. Its crude protein content and

digestibility vary according to plant age and season from 6 - 27% and 42 - 79% respectively (Lascano *et al*., 1990; Thiagalingam *et al*., 1997; Pholsen *et al*., 2000). Dry matter yields of 4 – 9 t DM/ha and daily live weight gains of 460 – 540 g/animal have been reported in Australia on *C. pascuorum* ley pasture in comparison to live weight losses of 140 – 240 g/animal on native pasture (McCown *et al*., 1986). In the semi-arid/dry sub-humid Northern Territory of Australia, *C. pascuorum* remained the dominant pasture component after 5 years of stocking at 3.3 steers/ha, consistently producing dry season live weight gains of 20 - 50 kg/ha (McCosker, 1987; Thiagalingam *et al*., 1997).

The literature reviewed showed positive results of legume inclusion in improving pasture productivity indices. Similar to what obtains in some other tropical environments, the hypothesis is that legumes can play significant role in range rehabilitation works in Nigeria. Thus, the three forage legumes (*S. hamata, C. rotundifolia* and *C. pascuorum*) were assessed in strip-sowings in the dry sub-humid Guinea Savanna as alternative means of range improvement for enhancing primary production and subsequent performance of animals grazing the treated pastures.

# CHAPTER 3

## 3.0 MATERIALS AND METHODS

The study was planned and conducted in two phases encompassing three rainy seasons for a total trial period of 28 months (2004-2006). The first phase covering a trial period of 16 months examined the feasibility of range improvement by strip-sowing of forage legumes into natural pastures. Data on establishment and forage dry matter yield were collected for the sown legumes and the natural pasture. In the second phase, Bunaji cattle were introduced to graze the treatments continuously over the next 12 months of the study. During the grazing period, animal performance was measured as monthly body condition score and fortnightly liveweight changes. The persistence and spread of the legumes into the surrounding native pasture was determined after the grazing period.

### 3.1 STUDY AREA

The study was conducted at the National Animal Production Research Institute, Shika, Ahmadu Bello University Zaria in the Northern Guinea Savanna zone of Nigeria. The location is at an elevation of 702 m above sea level, located on Latitude 11$^{o}$12’59’’N; and Longitude 07$^{o}$33’40’’E (Google earth, 2012). Long term climatic data of Shika indicate mean total annual rainfall of 1,100 mm, almost all of which falls between May and October. The rainfall pattern is unimodal with the peak in August. The mean relative humidity during the rainy season is 72% while the mean daily temperature is 24.8$^{o}$C. The rainy season is followed by a cool dry, dusty harmattan period (December to February) with daily mean temperatures as low as 14$^{o}$C and relative humidity of about 21%. A hot dry period with mean daily temperatures as high as 31$^{o}$C and relative humidity of 27%

follows between the months of March and April. Almost all plant growth and hence forage accumulation occurs during the rainy season (May to October).

The soil of the study site is mainly the tropical ferruginous type, with a few iron concretions of lateritic iron stones present. Soils have good drainage and are exposed to high nutrient losses through leaching and soil erosion. Nitrogen and phosphorus are the critical limiting elements (Kowal and Kassam, 1978). The top soil (0-15cm) chemical composition the site has been reported as 10% clay, 11% silt, 79% sand, 5.6 pH, 0.030% total N, 11.9 ppm total P, 12.7 meq/$100^{+}$ Ca, 0.098meq/$100^{+}$ $K^{+}$, and 0.118 meq/$100^{+}$ $Mg^{+}$ (Omokanye *et al*., 2002). A five-year rainfall data (2002-2006), encompassing the study period which was obtained from NAPRI, Shika is presented in Table 2. A ten-year mean monthly rainfall pattern from the same station is presented in Figure 1.

Table 2: Five-year rainfall (mm) distribution at Shika 2002-2006 during the trial

| | Years | | | | |
|---|---|---|---|---|---|
| Month | 2002 | 2003 | 2004 | 2005 | 2006 |
| January | 0 | 0 | 0 | 0 | 0 |
| February | 0 | 0 | 0 | | 0 |
| March | 19.9 | 0 | 13.6 | 0 | 0 |
| April | 69.6 | 31.0 | 7.8 | 63.1 | 1.8 |
| May | 10.6 | 78.4 | 162.8 | 113.1 | 202.5 |
| June | 133.1 | 69.2 | 190.5 | 160.2 | 426.5 |
| July | 229.0 | 243.1 | 245.0 | 152.6 | 232.2 |
| August | 201.4 | 427.1 | 308.1 | 235.5 | 222.0 |
| September | 218.8 | 219.5 | 126.3 | 122.4 | 275.0 |
| October | 125.2 | 67.1 | 20.8 | 16.8 | 28.5 |
| November | 0 | 0 | 0 | 0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 |
| Annual rainfall | 1007 | 1135.4 | 1074.9 | 863.7 | 1088.5 |
| Annual rain days | 87 | 87 | 73 | 74 | 71 |

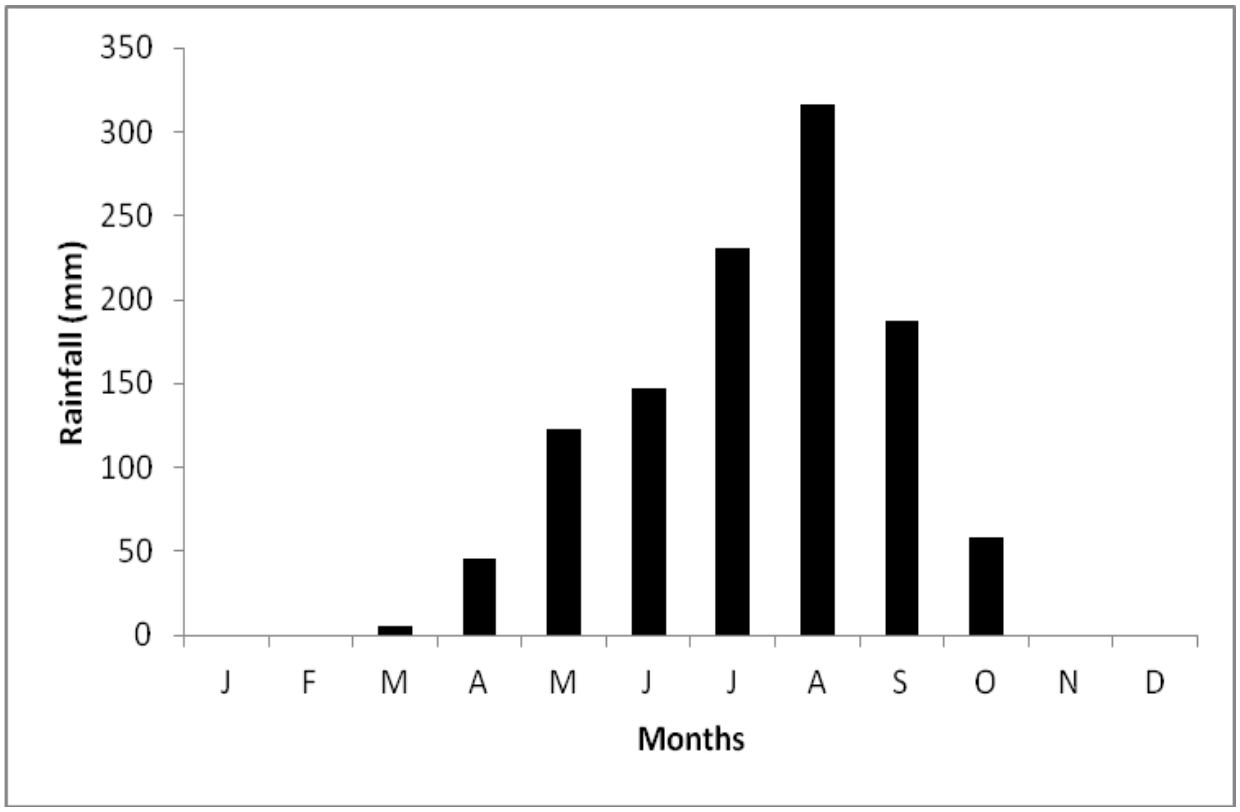



Figure. 1: Pattern of a ten-year (1997-2006) mean rainfall for Shika

## 3.2 EXPERIMENTAL DESIGN

The experimental design was a randomized block design on an 8 ha field of natural range divided into 4 blocks of 2 ha. Blocking was done according to soil depth and slope of the field (Appendix 2). Each of the 2 ha blocks was further sub-divided into 4 equal paddocks measuring 50 x 100m (0.5ha). The treatments imposed were strip-sowings of *Stylosanthes hamata* cv Verano, *Chamaecrista rotundifolia* cv. Wynn, and *Centrosema pascuorum* cv Calvacade into natural range pasture with the natural range pasture as the control treatment. These treatments were designated as I, II, III and IV, respectively and replicated four times. Replicates I and III were on deep soils while replicates II and IV were on shallow soils respectively. Similarly, replicates I and II were on the lower slope while replicates III and IV were on the upper slope. Botanical inventory of the experimental site was taken before the introduction of the legumes (Appendix 1). The site has been an open access rangeland for the Institute's cattle and is subjected to continuous grazing year round without any improvement.

## 3.3 LEGUMES ESTABLISHMENT

A preliminary germination test was carried out on the seeds by selecting 300 seeds of each of the three test legumes. The seeds of each legume were randomly divided and assigned into 3 replicates of 100 seeds in separate petri dishes layered with moistened filter paper. Germination was considered complete with breakage of seed coat and emergence of the primodial plumule and radical. The process was monitored daily by counting the number of seeds that had germinated. This continued for 15 days. Thereafter it was observed that mold had started growing in the petri dishes and the monitoring was terminated. Table 3 shows the record of germinations of the legumes over the 15 days

test period. The results were used to determine the seeding rates as pure germinable seeds (PGS) in the strips sown with the legumes. In each of the treatment paddocks, five strips each measuring 2.5 m wide were ploughed up and harrowed using a tractor and seeded with the respective legumes. The seeding rates were *S. hamata* at 30 kg/ha, *C. pascuorum* at 16 kg/ha and *C. rotundifolia* at 15 kg/ha. The sites were monitored year round for botanical composition, legume establishment and dry matter yields in the first year, as measures of range improvement. Subsequently, the regeneration of the respective legumes were monitored and finally in the fourth year, the persistence and spread of the legumes were measured by taking stand counts of the legumes on the strips and in the adjoining natural pasture to the strips.

## 3.4 BOTANICAL COMPOSITION AND DRY MATTER YIELDS

Botanical composition and dry matter production of the pasture were measured monthly by the BOTANAL method developed by Hargreaves and Kerr (1992). On each sampling date, five standards (quadrats) were visually identified to represent the highest to the lowest yield scored as 5 to 1 respectively. The procedure identifies the highest possible yield in the area followed by the lowest possible yield. The third quadrat which carried score three was identified to represent yield that was regarded as the one that was mid way between the highest and the lowest and the second and fourth scores were identified as quadrats that represented mid yields between first and third as 2 and third and fifth as 4. The five standards were marked and left for reference during the sampling. The sampling procedure was by casting the quadrat and scoring each as 1, 2, 3, 4 or 5 according to the standards. These standards were frequently checked to ensure that the scoring were representative of the standards. When the sampling had been completed for

the date, the standards were then cut and weighed fresh then dried up in the oven until they attained constant weight, then weighed again to determine their dry matter yields. Species occurrence was also being scored alongside with the determination of the dry matter yields as the species occurring in each quadrat were recorded, ranking the first three for abundance with 1 for most abundant, 2 for abundant and 3 for least abundant species, respectively.

### 3.5 ANIMAL PERFORMANCE

Following the establishment of the three legumes, Bunaji bulls aged about 2 years were introduced into the treatments with two animals per paddock. The animals were balanced for weight across treatments with mean liveweight of 130.5 kg to provide a stocking rate of 1.04 Tropical Livestock Unit per hectare (TLU/ha). A Tropical Livestock Unit is defined as the equivalence of 250 kg animal with a daily requirement of 6.25 kg of feed on dry matter basis (Jahnke, 1982) for one year. Animals were grazed by day (9:00 – 17:00 hrs daily) and kraalled overnight throughout the one year period. Liveweights were recorded fortnightly while body condition scores were taken on a monthly basis. Body condition was scored in accordance with standards described by Pullan (1978) on a scale of 1-5. Water and mineral salt block were supplied *ad lib* while grazing on pastures. The animals were dipped in Amitix solution against ectoparasites twice a month in the dry season and weekly during the rainy season. The animals were also dewormed at the start and mid way into the grazing trial with Albendazole administered at the rate of 1ml/10 kg liveweight to control the endoparasites.

## 3.6 STATISTICAL ANALYSIS

Data input and computation were done using the Microsoft Excel package (Microsoft, 2003). Data was subjected to Analysis of Variance using General Linear Model (GLM) and the means were separated using the Duncan's Multiple Range Test (DMRT). Trend Analysis was carried out (SAS, 2000). Graphs were plotted using Microsoft Excel package.

# CHAPTER 4

## 4.0 RESULTS

### 4.1 BOTANICAL COMPOSITION OF EXPERIMENTAL SITE

Botanical inventory carried out at the commencement of the study showed a wide variety and large numbers of plant species on the experimental site. The record revealed 85 plant species. The four major classes of vegetation found on the site were grasses, forbs, shrubs and trees. The species identification of the plants encountered is presented as Appendix 1. Summary of the data showing plant classes, their numerical abundance as well as percentage contribution to the biodiversity of the vegetation is presented in Table 3. A total of 67 plant *genera* were recorded on the site. This number is made up of 22 grass *genera*, 28 forbs/herbs *genera*, 11 shrubs *genera* and 6 tree *genera*. In terms of species, there were 31 grass species, 36 forbs/herbs, 12 shrub species and 6 tree species making up a total of 85 different plant species. Percentage contribution to the biodiversity of plants of the vegetation aggregated as grass, forbs/herbs, shrub and tree classes were 36.5, 42.4, 14.1 and 7.1 %, respectively. In the grass and forbs classes, 58% were annuals, while the remaining 42% were perennials showing that annuals were more predominant than the perennials. Legumes which were considered to be very important in the nutrition diets of grazing animals made up 19% of the under storey species. The lower and middle strata of vegetation define the upper limits of vegetation within which grazing activities occur. The grasses and forbs classes which usually contribute the bulk of diet consumed by grazing animals made up 78 % while the shrubs were 14 % of the total vegetation biodiversity. The under storey vegetation of grasses and forbs presented

greater diversity as compared to the middle stratum of shrubs or the upper stratum of trees. The least number of species were recorded in the trees, which formed the upper stratum of the vegetation. The middle and upper stratum of shrubs and trees (21.18 %) had comparatively fewer legumes with a contribution of 16.7% of the total vegetation diversity (Table 3).

Table 3: Inventory and botanical composition of the experimental site before strip-sowing legumes

| Vegetation Class | | Form of life cycle | Biodiversity of site | | |
|---|---|---|---|---|---|
| | | | No. of Genera | No. of Species | Species relative contribution (%) |
| Grasses | | Annual | 14 | 21 | 24.71 |
| | | Perennial | 8 | 10 | 11.77 |
| | | **Sub Total** | **22** | **31** | **36.48** |
| Forbs/Herbs: | Legumes | | | | |
| | | Annual | 8 | 13 | 15.29 |
| | | Perennial | 5 | 5 | 5.88 |
| | Others | | | | |
| | | Annual | 5 | 5 | 5.88 |
| | | Perennial | 10 | 13 | 15.29 |
| | | **Sub Total** | **28** | **36** | **42.34** |
| Shrubs | Legumes | | 2 | 2 | 2.35 |
| | Others | | 9 | 10 | 11.77 |
| | **Sub Total** | | **11** | **12** | **14.12** |
| Trees | Legumes | | 1 | 1 | 1.18 |
| | Others | | 5 | 5 | 5.88 |
| | **Sub Total** | | **6** | **6** | **7.06** |
| | **Grand Total** | | **67** | **85** | **100** |

## 4. 2 LEGUME ESTABLISHMENT AND REGENERATION

### 4.2.1 Seed Germination Test

The result of the germination test carried out is presented in Table 4. Before the germination test was carried out, some properties of the seed were determined; these included: seed purity, 1000-seed weight and number of seeds in every kilogram of the legumes under the study. The result showed that *S. hamata* had the lowest purity while *C. pascuorum*, had the highest purity. *C. pascuorum* seeds were bigger and heavier than either the seeds of *S. hamata* or *C. rotundifolia*. Variability in seed rates was based on the differences in seed purity and seed number per kilogram of seed batch. *S. hamata* recorded higher germination per cent while *C. rotundifolia* and *C. pascuorum* recorded similar germination per centage. Seed number in a batch of 1kg seed was highest in *C. rotundifolia* and least in *C. pascuorum*.

Results of the legumes field establishment and regeneration over a period of three years are presented in Table 5. In the first year of establishment, *S. hamata* had the highest germination count of 117.3 stands / $m^2$. This was significantly higher ($P<0.05$) than those of *C. pascuorum* (65.2 / $m^2$) and *C. rotundifolia* (24.6/$m^2$). *C. rotundifolia* had the lowest stand count during the year of establishment but its stand count in the second year as self-regenerated plants was significantly higher ($P<0.01$) than the other two legumes. The stand count in *S. hamata* and *C. pascuorum* declined to 32.1 stands /$m^2$ and 55.6 stands / $m^2$ respectively in the second year. Establishment count in *C. rotundifolia* further increased to 143.0 stands / $m^2$ in the third year of establishment while *S. hamata* further dropped to 19.4 stands and *C. pascuorum* to 37.6 stands / $m^2$. Establishment count of

*C.rotundifolia* in the third year of establishment was significantly higher ($P<0.05$) than either *S. hamata* or *C. pascuorum*, while the differences between *S. hamata* and *C. pascuorum* in the same year of establishment was not significant ($P>0.05$).

Table 4: Seed rates, weight of 1000 seeds, number of seeds / kg, seed purity and germination of the tested legume species at NAPRI, Shika

| Legume | Seed rate (kg/ha) | 1000-seed weight (g) | Number of seed/kg | Seed Purity (%) | Germination[1] (%) |
|---|---|---|---|---|---|
| *S. hamata* | 30 | 3.10 | 322.581 | 38.7 | 43 |
| *C. rotundifolia* | 15 | 2.90 | 335,570 | 70.0 | 23 |
| *C. pascuorum* | 16 | 17.35 | 57,670 | 78.4 | 23 |

[1]Germination counts were conducted over 15 days

Table 5: Rainy season legume establishment (stands/$m^2$) in the year of establishment and subsequent self- regeneration in the second and third year

| | Forage Legumes | | | | |
|---|---|---|---|---|---|
| | *S. hamata* | *C. rotundifolia* | *C.pascuorum* | SEM | LOS |
| 1st year | 117.30[a] | 24.58[c] | 65.16[b] | 8.20 | *** |
| 2nd year | 32.14[c] | 67.08[a] | 55.55[ab] | 8.20 | * |
| 3rd year | 19.42[b] | 143.03[a] | 37.64[b] | 8.20 | *** |

Means along rows with different superscripts are significantly different (P<0.05)
***= P<0.001
*= P<0.05

### 4.2.2 Effect of Soil Depth on Legumes Establishment

Table 6 shows the establishment and regeneration of different legumes stand counts on deep and shallow soils of the experimental site. The result showed that both soil type and species genotype are important in the establishment of the different legumes. Within each soil type significant differences ($P<0.05$) were observed. *C. rotundifolia* recorded significantly higher ($P<0.05$) stand counts than *S. hamata* and *C. pascuorum*. Within genotype, establishment was better on deep than on shallow soil for *S. hamata* and *C. rotundifolia.* The performance of *C. pacuorum* was similar in establishment for both soil types with a stand count of 52.8 / $m^2$.

Year and soil interaction was also significant. In the year of establishment, legume count was significantly higher ($P<0.05$) on the shallow soil than on the deep soil. However, in the two years following establishment, regeneration on the deep soil was better ($P<0.05$) than on the shallow soil. Relative to the plant population in the year of establishment, regeneration of plants was significantly ($P<0.001$) lower in number. This number rose in the third year in both shallow and deep soil (Figure 2).

Table 6: The effect of Soil depth on three forage legumes establishment (stands/ $m^2$)

| | Stands of legumes ($m^{-2}$) | | | | |
|---|---|---|---|---|---|
| Soil Type | *S. hamata* | *C. rotundifolia* | *C.pascuorum* | SEM | LOS |
| Deep soil | $61.73^{b}$ | $80.45^{a}$ | $52.76^{b}$ | 6.70 | * |
| Shallow soil | $50.84^{b}$ | $75.98^{a}$ | $52.80^{b}$ | 6.70 | ** |

Means within row with different superscripts are significantly different ($P<0.05$).

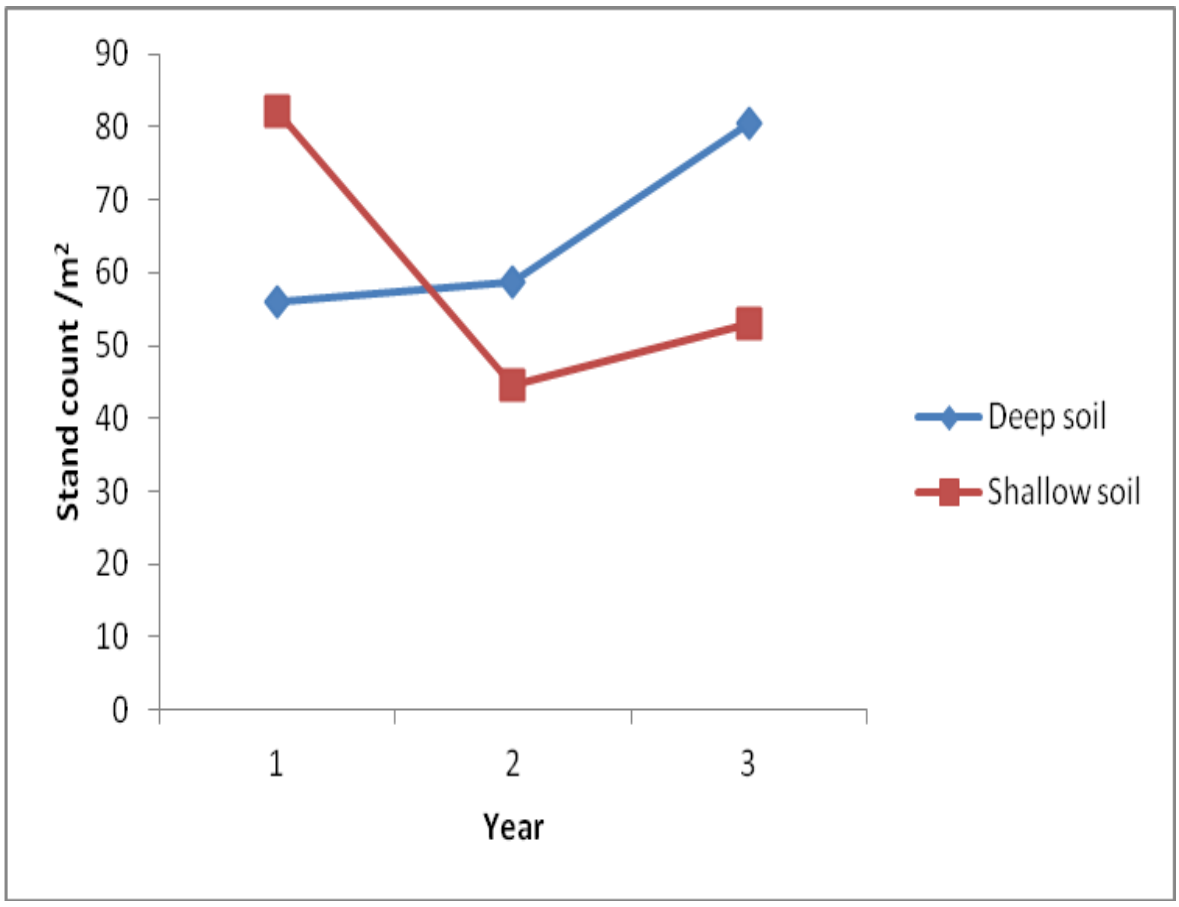



Figure 2: Trend of legume stand establishment on deep and shallow soils in a three year period in the Northern Guinea Savanna Nigeria

### 4.2.2 Legumes Regeneration

The source of regenerated stands of legumes from seed and surviving stumps are presented in Table 7. The results showed that the three legumes regenerated mainly from seeds as new seedlings and not regrowths from shoots of surviving stumps of the previous year's stands. Regrowths in *S. hamata* was 12.7 % while there was only 0.08% for *C. rotundifolia* and zero regrowth in *C. pascuorum*.

Phenology observations and grazing condition of the different sown strips of legumes are shown in Table 8. By the end of June, *C. rotundifolia* had about 50% of its stands in flower while *S. hamata* had only 8% of its stands in flower. *C. pascuorum* was mainly at the vegetative stage with no visible flowers observed. The flowering plants in *C. rotundifolia* were from plants that germinated from seed at the beginning of the wet season of the current year. The flowering plants from *S. hamata,* on the other hand, were the regrowth of old stumps from the previous year, with no flowers on stands having emerged from seeds in the season. The herbivory activities of rodents and insects pests was significantly high ($P<0.001$) in *C. pascuorum* (55%). Pest attacks were low in *S. hamata* and *C. rotundifolia,* with a record of only 4% and 2% of their stands attacked respectively.

Table 7: Sources of regenerated stands (Number/$m^2$) of three forage legumes at the early vegetative stage in the native rangeland

| Legumes | Number of new Seedlings | Number of re-growth from stumps | Total number of stands |
|---|---|---|---|
| *S. hamata* | $22.7^{b}$ (87.64) | $3.3^{a}$ (12.74) | $25.9^{b}$ |
| *C. rotundifolia* | $132.3^{a}$ (99.92) | $0.2^{b}$ (0.08) | $132.4^{a}$ |
| *C. pascuorum* | $28.8^{b}$ (100.00) | $0.0^{b}$ (0.00) | $28.8^{b}$ |
| SEM | 7.1 | 0.6 | 7.2 |

Values in the same column with different superscripts are significantly different ($P<0.05$),
Values in parenthesis are percentages

Table 8: Phenology observations and grazing attacks on three forage legumes at the beginning of the rainy season

| Legume | Total stand count /$m^2$ | Stands in flower | No. grazed stands |
|---|---|---|---|
| *S. hamata* | $25.9^{b}$ | $2.1^{b}$ (8.10) | $1.1^{b}$ (4.24) |
| *C. rotundifolia* | $132.4^{a}$ | $65.8^{a}$ (49.70) | $2.3^{b}$ (1.74) |
| *C. pascuorum* | $28.8^{b}$ | $0.0^{b}$ (0.00) | $15.9^{a}$ (55.21) |
| SEM | 7.2 | 5.2 | 1.6 |

Values in the same column with different superscripts are significantly different ($P<0.05$)
Values in parenthesis are percentages

Soil depth had no significant ($P>0.05$) effect on regrowth and herbivory but significantly ($P<0.05$) influenced total stands, regeneration from seed and the number of stands in flower. In all the three parameters considered, plants on the deep soil performed better than those on the shallow soils. Values obtained from the shallow soil were 50% of the values obtained on deep soil (Table 9).

Table 9: Sources of regenerated legume (stands/$m^2$) on deep and shallow soil

| Soil type | Total stands | Seedlings | Re-growth | No. in flower | Herbivory |
|---|---|---|---|---|---|
| Deep soil | 80.7[a] | 79.8[a] | 0.9 | 29.6[a] | 8.0 |
| Shallow soil | 44.0[b] | 42.8[b] | 1.3 | 15.7[b] | 4.9 |
| SEM | 5.8 | 5.8 | 0.5 | 4.3 | 1.3 |

Values within columns bearing different superscripts are significantly different ($P<0.05$)

## 4.3 DRY MATTER YIELD FROM STRIP-SOWN LEGUMES

The available forage in legume strips was determined as dry matter yield. The result showed that total dry matter yield was highest ($P<0.05$) in strips of *S. hamata* and least in the strips of *C. pascuorum*, respectively (Table 10). The total dry matter yield in *S. hamata* (1.4 t / ha) was significantly higher ($P<0.01$) than yield from *C. rotundifolia* strips (1.07 t / ha) which in turn was significantly higher ($P<0.001$) than the total dry matter yield from strips of *C. pascuorum* (0.88 t DM / ha).

Separation of the total dry matter yields into legumes, grasses and forbs in the different treatments showed that in all the treatments, contribution from grasses were higher than the sown legumes. While grasses contributed 49.7%, 48.4% and 75.6% in *S. hamata, C. rotundifolia* and *C. pascuorum* strips, respectively, the legume components were 41.9 %, 46.9% and 3.4 % in the respective legume treatments. Non leguminous forbs made the least contribution of 8.5 %, 4.6 % and 21.0 % in *S. hamata*, *C.rotundifolia* and *C. pascuorum* strips in that order. Vegetation cover in the strips were 33.3 %, 33.1 % and 27.2 % for *S. hamata*, *C.rotundifolia* and *C. pascuorum*, respectively but were not significantly different ($P>0.05$) from one another. Similarly, there were no significant differences ($P>0.05$) in yields of grass component. Significant differences ($P<0.05$) were, however, observed in the yields of the legume components, forbs and the total yields.

## 4.4 DRY MATTER YIELDS FROM THE NATIVE PASTURE

Mean dry matter production from the native pastures in the unimproved treatment was 3.07 t/ha which was significantly higher ($P<0.05$) than yield from legume strip-sown pastures. *S. hamata* treatment was not significantly different from yield in *C. pascuorum* or *C. rotundifolia* treatments (Table 11). Results presented showed that dry matter yield was highest during the late rainy season and lowest during the late dry season. Dry matter production in the strip-sown and control native pasture varied from 0.4 to 4.9 t / ha in *S. hamata*, 0.5 to 5.2 t / ha in *C. rotundifolia*, 0.5 to 5.7 t / ha in *C. pascuorum* and 0.6 to 7.3 t / ha in the control native pastures.

Table 10: Pasture composition, dry matter yields and ground cover in legume strips at commencement of grazing trial by test animals.

| | | Dry matter yield (kg/ha) | | | |
|---|---|---|---|---|---|
| | Ground cover (%) | Legume | Grass | Forbs | Total |
| *S. hamata* | 33.28 | 585.60[a] | 694.10 | 118.10[a] | 1397.80[a] |
| *C. rotundifolia* | 33.13 | 501.10[a] | 517.20 | 49.60[b] | 1067.90[b] |
| *C. pascuorum* | 27.19 | 30.00[b] | 661.70 | 183.80[a] | 875.50[c] |
| SEM | 3.9 | 79.3 | 95.4 | 35.6 | 70.1 |
| LOS | NS | *** | * | ** | |

Values in the same columns with different superscripts are significantly different (P<0.05)
LOS= Level of Significance: NS= not significant, ***= P<0.001)

Table 11: Herbage available as dry matter yields (t/ha) from legume strip-sown and non-treated native pastures during the different seasons in the Northern Guinea Savanna of Nigeria.

| | *S. hamata* | *C. rotundifolia* | *C. pascuorum* | Native | SEM | LOS |
|---|---|---|---|---|---|---|
| Early dry (Oct-Dec) | 1.97 | 1.91 | 1.89 | 1.96 | 0.10 | NS |
| Late dry (Jan-Mar.) | $0.41^{b}$ | $0.47^{ab}$ | $0.47^{ab}$ | $0.56^{a}$ | 0.03 | * |
| Early Rain (Apr-Jun) | $2.59^{ab}$ | $2.86^{a}$ | $2.34^{b}$ | $2.47^{ab}$ | 0.14 | * |
| Late rain (Jul-Aug) | $4.88^{b}$ | $5.18^{ab}$ | $5.70^{ab}$ | $7.30^{a}$ | 0.53 | * |
| Mean | 2.46 | 2.61 | 2.60 | 3.07 | | |

a, b Means with different superscripts in rows are significantly different ($P<0.05$); SEM = standard error of mean; LOS= Level of significance

## 4.5 LEGUME SPREAD INTO NATIVE PASTURE

In the third year of the trial, the spread of the sown legumes into the adjoining native pastures was determined as seedlings found in pastures adjoining the strips. The results showed that *C.rotundifolia* recorded up to 19 stands / $m^2$ in the adjoining native range pastures while both *S. hamata* and *C. pascuorum* recorded less than 1 stand/$m^2$ (Figure 3). Soil depth had no influence on legume spread into the adjoining native range.

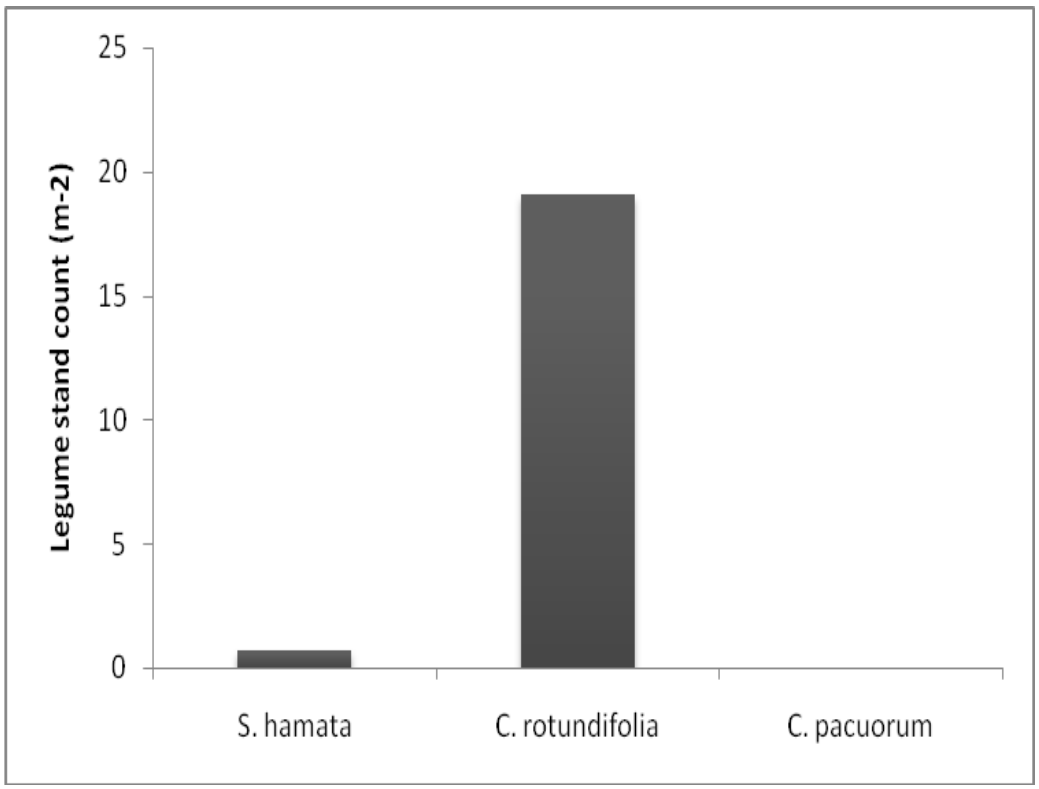



Fig. 3: Legume spread (stands/$m^2$) into adjoining native pasture three years after establishment

## 4.6 ANIMAL PERFORMANCE

Data analyzed for the one-year grazing cycle showed that treatments had no significant effect ($P>0.05$) on body weight, weight gains and body condition scores of the grazing animals. However, season had significant influence ($P<0.001$) on the body weight changes. Forage production and soil depth interaction significantly influenced ($P>0.05$) body condition scores.

### 4.6.1 Effect of Treatments on Liveweights, Weight Changes and Body Condition Scores

Although there were no significant differences ($P>0.05$) in the body weights of animals on the different treatments imposed, but animals on *C. rotundifolia* tended to have higher absolute body weight of 150.25±6.89 kg while those on unimproved native pasture (control) had the least body weights of 147.34±6.89 kg (Figure 4). Weight gains of the animals across all the treatments which ranged between 11.44±1.64 kg in *C. pascuorum* treatment to 13.22±1.64 kg in *S. hamata* were not significantly different ($P>0.05$). Body condition scores (BCS) were also not significantly different ($P>0.05$) in all the treatments. The body condition scores ranged from 3.30±0.09 in animals grazing *C. rotundifolia* treatment to 3.53±0.09 in animals on *S. hamata*.

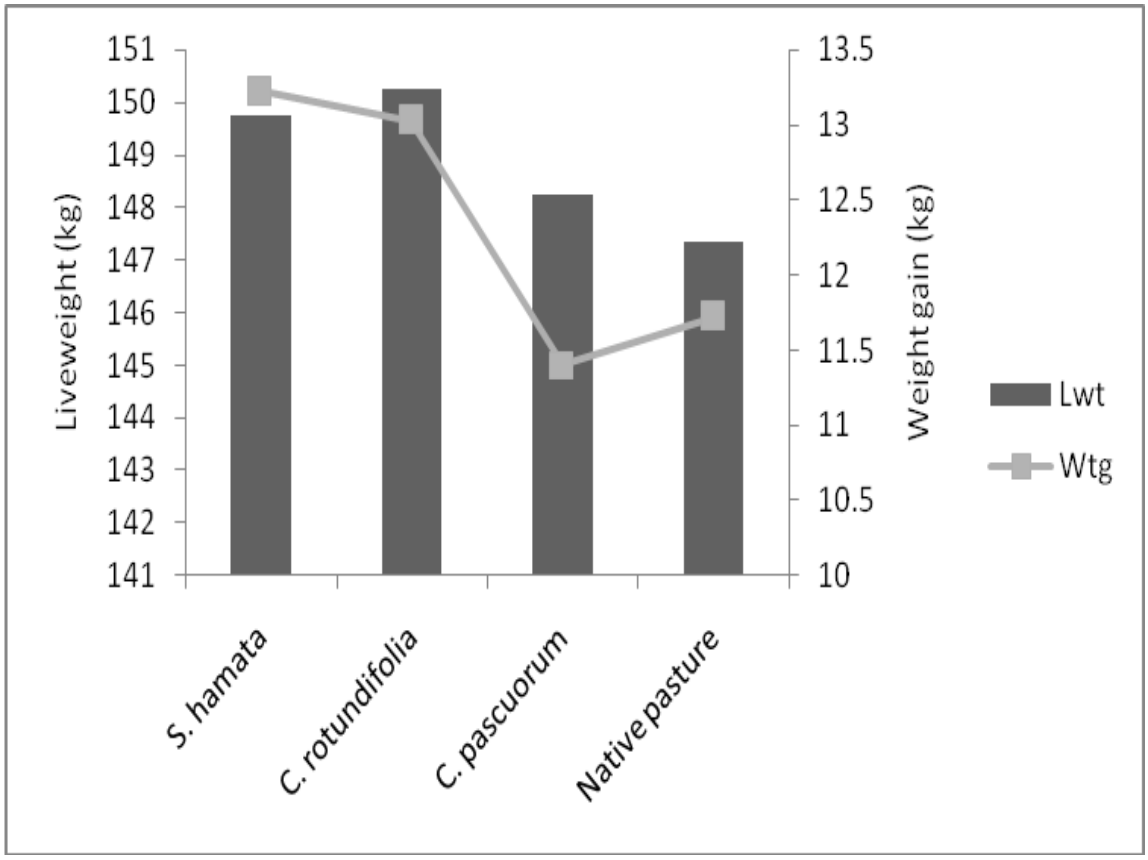



Figure 4: Liveweights (Lwt) and weight Changes (Wtg) of Bunaji bulls grazing different legume-strip-sown rangeland pastures in the Northern Guinea Savanna of Nigeria.

### 4.6.2 Effect of soil depth on Animals performance

Table 12 shows the mean body weight, weight changes and body condition scores of the young Bunaji bulls grazing the different treatments. The results showed that there were no significant differences ($P>0.05$) in all the three parameters measured on the animals grazing the pastures on either of the soil types. However, the absolute values of animal weights grazing pastures on the deep soils were higher than those on the pastures of the shallow soils. The values of weight changes and body condition scores were rather inconsistent in respect of pastures of deep or shallow soils.

Table 12: The influence of legume species and soil depth on the performance of grazing young Bunaji bulls

| | | Deep Soil | | | | | |
|---|---|---|---|---|---|---|---|
| Soil depth | Parameter | *S. hamata* | *C.rotundifolia* | *C. pascuorum* | Native | SEM | LOS |
| | Body weight | 157.75 | 155.06 | 149.69 | 149.94 | 9.75 | NS |
| Deep soil | Weight gain | 14.56 | 12.75 | 10.88 | 12.31 | 2.32 | NS |
| | BCS | 3.66 | 3.47 | 3.25 | 3.28 | 0.1 | NS |
| | Body weight | 141.75 | 145.44 | 146.81 | 144.75 | 9.75 | NS |
| Shallow soil | Weight gain | 11.88 | 13.31 | 12.00 | 11.31 | 2.32 | NS |
| | B CS | 3.41 | 3.13 | 3.56 | 3.50 | 0.13 | NS |

LOS= Level of Significance
NS= Not significant

### 4.6.3 Effect of Season on Animal Performance

Pattern of body weights and weight gains of the young bulls grazing the pastures in the different seasons of the year are presented in Figure 5. Season had significant effects on body weights and weight gains ($P<0.001$) but not on body condition scores ($P>0.05$). Body weights during the late dry and early rainy seasons were not significantly different ($P>0.05$). Likewise, body weights during the late rain and early dry seasons were not significantly different ($P>0.05$) but higher in the later season. Body weights of animals grazing the pastures during the late rainy and early dry seasons were significantly higher ($P<0.05$) than weights attained in the late dry season and early rainy season.

The highest weight gain of 30.4kg was recorded during the early rainy season which was significantly higher ($P<0.001$) than the three other seasons. Weight gains in the late rainy and early dry seasons were not significantly different ($P<0.05$) and the least gain of 1.1kg was recorded during the late dry season which was significantly lower ($P>0.05$) than the weight gained by the animals during the late rainy season and the early dry season (Figure 5).

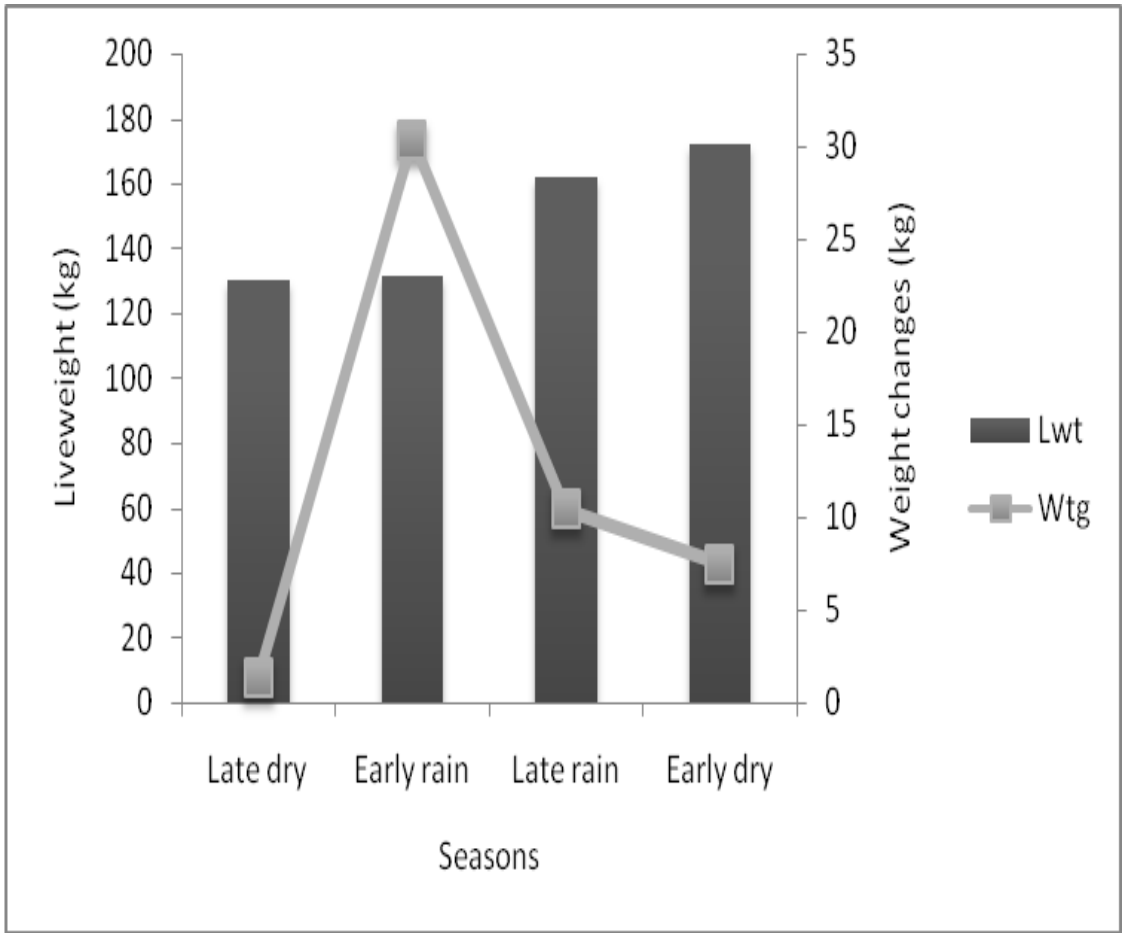



Fig. 5: Liveweights (Lwt) and weight changes (Wtg) of young Bunaji bulls grazing native pastures in different seasons of the year

### 4.6.3 Effect of Season and Legume Interaction on Animal Performance

Results of the body weight of the young Bunaji bulls grazing the different legume-improved native pastures across the seasons is presented in Table 13. Within season comparison across the treatments showed no significant differences ($P>0.05$). However, when weights were compared across the seasons in the treatments, the results showed that season had a highly significant effect ($P<0.001$) in *S. hamata* and *C. rotundifolia* treatments but none in animals grazing the *C. pascuorum* and the native unimproved pastures. In all the treatments, the grazing animals attained their highest weights during the early dry season with animals on *C. rotundifolia* weighing more than those in other treatments. Animals grazing the native pastures had the least weight.

Table 13: Liveweight changes (kg) of Bunaji bulls grazing improved and unimproved native pasture in a year cycle

| Season | *S. hamata* | *C. rotundifolia* | *C. pascuorum* | Native |
|---|---|---|---|---|
| Late dry season | 130.13[b] | 130.38[b] | 130.25 | 130.25 |
| Early rainy season | 133.25[ab] | 127.88[b] | 133.50 | 130.88 |
| Late rainy season | 162.00[ab] | 167.38[ab] | 159.25 | 158.50 |
| Early dry season | 173.63[a] | 175.38[a] | 170.00 | 169.75 |
| SEM | 13.78 | 13.78 | 13.78 | 13.78 |
| LOS | * | * | NS | NS |

Means in columns bearing different superscripts are significantly different (P<0.05); SEM = standard error of means; LOS= Level of Significance

### 4.6.5 Animal liveweight changes

The statistical analysis showed that only season had significant effect ($P<0.05$) on weight gain. The trend for season versus treatment interaction on weight gain is shown in Figure 6. The weight gain of animals in all treatments was lowest in the late dry season. Animals on *C. rotundifolia* treatment lost weight during the late dry season against the other treatments with gains of 0.63., 3.1 kg and 3.3 kg in native unimproved pasture, *S.hamata* and *C. pascuorum* pastures, respectively. Weight gain was highest in all treatments during the early rainy season. The animals in *C. rotundifolia* gained up to 39.5 kg which was significantly higher ($P<0.05$) than gains in the other treatments. The weight gain in the remaining three treatments were not significantly different ($P>0.05$) in that same season. During the late rain and early dry seasons, weight gains dropped and were not significantly different ($P>0.05$) in all the treatments.

Table 13 shows the results of liveweight, weight gain and body condition scores of the young Bunaji bulls grazing the pastures in a one year cycle. There was a steady increase in liveweight as the year advanced through the seasons in all the treatments. Animals attained their highest weights at the end of the early dry season grazing cycle. At the end of the one year grazing cycle, animals on *C. rotundifolia* had the highest mean liveweight of 175±13.78kg while those on unimproved native pasture had an average weight of 169±13.78kg. Liveweights gains recorded in all treatments were highest during the early rainy season.

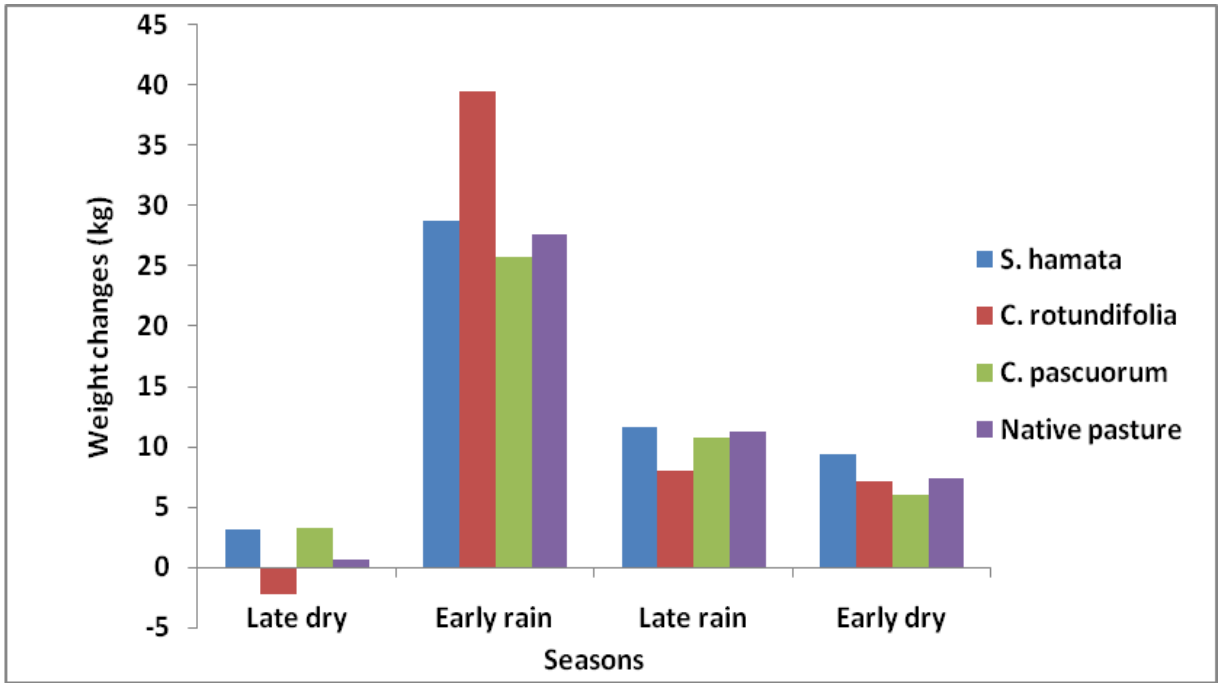



Figure 6: Weight changes of young Bunaji bulls on the different legume strip-sown treatments and control native pastures in the different seasons of the year.

Table 14: Seasonal liveweight changes (kg) and body condition scores of Bunaji bulls grazing legume improved and native pastures in a year cycle

| Season | Parameter | *S. hamata* | *C. rotundifolia* | *C. pascuorum* | Native | SEM |
|---|---|---|---|---|---|---|
| Late Dry Season | Liveweight | 130.13 | 130.38 | 130.25 | 130.25 | 13.78 |
| | Weight gain | 3.13 | -2.50 | 3.25 | 0.63 | 3.29 |
| | BCS* | 3.56 | 3.19 | 3.19 | 3.44 | 0.19 |
| Early Rainy Season | Liveweight | 133.25 | 127.88 | 133.50 | 130.88 | 13.78 |
| | Weight gain | 28.75 | 39.50 | 25.75 | 27.63 | 3.29 |
| | BCS | 3.50 | 3.19 | 3.44 | 3.25 | 0.19 |
| Late Rainy Season | Liveweight | 162.00 | 167.38 | 159.25 | 158.50 | 13.78 |
| | Weight gain | 11.63 | 8.00 | 10.75 | 11.25 | 3.29 |
| | BCS | 3.69 | 3.50 | 3.56 | 3.50 | 0.19 |
| Early Dry Season | Liveweight | 173.63 | 175.38 | 170.00 | 169.75 | 13.78 |
| | Weight gain | 9.38 | 7.13 | 6.00 | 7.38 | 3.29 |
| | BCS | 3.38 | 3.31 | 3.44 | 3.38 | 0.19 |

*BCS= Body Condition Score

# CHAPTER 5

## 5.0 DISCUSSIONS

## 5.1 VEGETATION COMPOSITION

The botanical composition of the trial site indicates a good cover of mixture of grasses, forbs and shrubs with few trees which are the feed resources of the natural rangeland. The grass vegetation is a fairly homogeneous mixture of perennial tussock grasses similar to that reported by de Leeuw (1971), Smith, (1992) and Kallah (2004). de Leeuw (1971), listed *Loudetia simplex*, *Andropogon ascinoidis, A. schirensis*, and *Monocymbium ceresiiforme* as species growing on shallow soils, while *Andropogon gayanus, Urelytrum muricatum*, *Elionurus popeguinii* and *Panicum phragmitoides* grow on the deep soils with annual and perennial *Hyparrhenia* spp found on both soil types. These, according to de Leeuw (1971), form the characteristic elements of the Northern Guinea Savanna zone if it has not been much disturbed. The findings in this report show that the grass cover forms a fairly stable community, having remained unaltered for over 30 years. The herbaceous cover is richly endowed with a large number of forbs, but their vigor has been reduced due to annual fires and grazing activities of cattle. The shrubs and trees are rather few and this is not unconnected with the effect of yearly fire outbreaks which kill seedlings of the woody species and the high rate of fuel wood extraction by the surrounding communities. The trees species listed are in agreement with Aregheore (2005), who listed the dominant tree species in the zone to include *Isoberlinia doka, Parkia biglobosa, Butyrospermum paradoxum* and *Khaya senegalensis* forming the bulk of the scattered woodlands. The vegetation composition of the study site is typical of the

savanna ecosystem described by Scholes and Hall (1996), White *et al.*, (2000) and Samiento (1992), as one with a well developed grass cover, 10-15% woody plants, less than 10% tree cover and usually maintained by fire, grazing and drought. The present study showed that grasses contributed 36.47%, shrubs 14%, forbs/herbs 42% while the trees made up of only 7% to the total vegetation inventory of the site.

Although the forbs/herbs contribute high percentage of species occurring in the study site, they did not contribute much to the total biomass production for livestock. The forage resources were still intact but due to the close grazing and the annual fires which they were continuously subjected to, the vigor of most of the species had been depressed. However, *Andropogon gayanus* and *Hyparrhenia* spp still grew up to 2m high on the deep soils (de Leeuw, 1971). This suggests that with proper management like reseeding, controlled grazing and protection from annual fire, it is possible to reverse the deterioration of the rangelands in the Northern Guinea Savanna zone and allow the recovery of native species.

Scattini *et al*. (1988) reported that while forbs ranked high in terms of species composition; they usually contribute a small component of the total pasture yield. Solbrig *et al.* (1996) reported that herbaceous leguminous plants though an important floristic component of the savannas, frequently contribute less than 1% of total biomass of the herbaceous layer. Herbaceous legumes in this study constituted 21.2 % of the total species occurrence. Smith (1992) had earlier reported that, native legumes yields on native grasslands are usually very low due to more selective grazing by stocks especially

during the dry season. Native legumes are very important in the nutrition of grazing animals, especially in the dry season. They serve as supplements to the poor quality natural pastures and also in the rehabilitation of denuded grazing land (Njarui *et al.,* 2004).

## 5.2 LEGUMES ESTABLISHMENT

Legumes vary widely in their ability to become established, produce and persist in different soils, climatic, pests / diseases, and management conditions (Miller *et al.*, 1988). The result of the germination test showed that *S. hamata* recorded the highest germination percentage. Under field conditions, *S. hamata* germinated more than either *C. rotundifolia* or *C. pascuorum*. While the standard germination test showed that both *C. rotundifolia* and *C. pascuorum* did not differ in their germination percentage, *C. pascuorum* germination was higher in the year of establishment. The establishment of the different legumes in this trial disagrees with the results of Jama (1998), where it was reported that *C. rotundifolia* had the highest seedling count in the year of establishment followed by *S. hamata* with *C. pascuorum* registering the least stand counts.

The level of seedbed preparation affects the germination and establishment of sown forage legumes (Skerman *et al.,* 1988). Other contributing factors may include seeds scarification and activities of harvester ants or both. Miller *et al.,* (1988) recommended a level of 20 to 40% hard seed as an insurance against false starts of the growing season. In the present study, there was no scarification. Seeds were allowed to remain dormant till the next growing season under field conditions such that as soon as they received

adequate moisture the following season, they germinated and augmented whatever stands survived the dry season. Of the three legumes, only *C. rotundifolia* showed progressive increase in stands as the years advanced, while the other two legumes kept decreasing with the advancement of years. In reports by Peters *et al.* (1994) Tarawali, (1994) Tarawali *et al.*, (1999) and Jama, (1998) it was noted that only *C. pascuorum* showed a declining trend in its regeneration while both *C. rotundifolia* and *S. hamata* were building up their stand population. Generally, the performance of the legumes in the present trial was not as good as that reported by Peters *et al*. (1994a) Tarawali, (1994); Tarawali *et. al.,* (1999) and Jama, (1998). The difference recorded is expected because the present trial was conducted in the drier Northern Guinea Savanna zone, while those studies reported were conducted in the moist subhumid Savanna zone and on well prepared seed beds with weeds controlled. The effect of rainfall on establishment of these legumes has been demonstrated in Kenya (Njarui *et al*., (2004) where the legumes were sown in three different locations receiving different amounts of total annual rainfall, the location with the highest rainfall recording highest plant counts while that with lowest rainfall recorded the lowest plant stand counts. According to Miller *et al*., (1988), a stand count of one plant of legume per meter square is adequate. Thus, the establishment in this study may be considered successful since no legume recorded less than 10 stands/$m^2$ in all the three years of trial.

*S. hamata* and *C. pascuorum* recorded higher stand count than *C. rotundifolia* only in the year of establishment. From the second year, *C. rotundifolia* overtook both *S. hamata* and *C. pascuorum* in stand count and this was maintained to the end of the third year.

Peters (1992) and Tarawali (1995) reported good establishment cover and yield in *C. pascuorum* in the first year that disappeared subsequently, while *S. hamata* was slow in establishment but survived for a number of years except that it did not remain green throughout the dry season. The better performance of *C. rotundifolia* over *S. hamata* or *C. pascuorum* has also been reported in Nigeria by Jama (1998) and in Kenya by Njarui *et al.,* (2004). *C. rotundifolia* has been reported to be of medium to low palatability with no known insect or pest attack (Ahn *et al*., 1988; Partridge and Wright, 1992; Quirk *et al*., 1992). This gives it an advantage over the other two legumes in terms of survival, seed yield and consequent regeneration over time. Observations in the present trial showed that while stand counts in *S. hamata* and *C. pascuorum* declined with time, *C. rotundifolia* was building up. Another advantage *C. rotundifolia* has over the other legumes is that it starts flowering very early following germination. Flowering starts as early as 6 weeks post-planting. Flowering and pod yield continues as long as there is enough moisture in the soil (Skerman *et al*., 1988). In moist environments, *C. rotundifolia* is known to produce seed year round and is also reported to produce below ground seeds (amphicarpic). It has been reported to produce as much as 800kg (Skerman *et al*., 1988) to 1.5t of seed/ha with a kg of seed having between 200,000 – 470,000 seeds (Cook *et al*., 2005). *C. rotundifolia* is only consumed after the plant has dried out and the pods have shattered, scattering the seeds. These characteristics of *C rotundifolia* enables it produce a lot of seed which shatters into the surrounding area thus spreading fast naturally into adjoining land making it a potential material for use in range rehabilitation.

*Stylosanthes hamata* on the other hand has been widely used for grazing purposes and improvement of rangelands (Haggar *et al.,* 1971; Gillard, 1977; McKeague *et al,*. 1978; Gardener, 1980; Mohammed-Saleem *et al.,* 1986; Agishi and de Leeuw, 1986). It is lightly grazed during the growing season, but becomes more acceptable when dry at which point the seeds would have matured and dropped to support good regeneration from seed in the subsequent year. Unlike *C. rotundifolia, S. hamata* flowers in 9 to 11 weeks post - planting and both vegetative growth and flowering can continue throughout the growing season with seed yields generally between 300 - 600 kg/ha (Skerman *et al*., 1988).

*C. pascuorum* seeds about 5 months after sowing and yields 250 - 1,500 kg/ha of seed. It is the most palatable of the three legumes and is grazed by cattle even when it is green (Skerman *et al.,* 1988). Observations in this trial showed that over 90% of *C. pascuorum* stands were clipped by rodents or attacked by insect pests while the other two legumes were virtually unaffected by rodents or insects. The finding here is at variance with that of Jama (1998) where it was reported that herbivory of all the three legumes were equally low. In this trial *C. pascuorum* was closely grazed by wild rabbits as their droppings and patches of their urine were common in *C. pascuorum* strips but absent in the strips sown to either *C. rotundifolia* or *S. hamata.* That probably accounts for the poor stand count in *C. pascuorum* in the second and third year of the trial which corroborates the findings of Tarawali *et al*. (1999). Consumption of the immature pods prevents seed production.

The pods are quite prominent and are easily picked by grazing herbivores ever before they ripen and shed seed, and because it is an annual and depends solely on seed drop for

regeneration in the subsequent year. Although *C. pascuorum* is more palatable and capable of producing high dry matter yields it hardly survives three years in a pasture. It may, therefore, be unsuitable for range improvement or rehabilitation. *S. hamata* and *C. rotundifolia* are capable of regeneration both from seed and perennating stumps and are sustained even after fire (Tarawali and Pamo, 1992) which would make them more suitable for the rehabilitation of degraded rangelands in the less humid Northern Guinea Savanna areas of Nigeria.

## 5.3 EFFECT OF SOIL DEPTH ON LEGUMES ESTABLISHMENT

Soil depth, which usually has positive relationship with soil fertility, plays a very significant role on the type of vegetation it supports. Deep soils are preferred over shallow soils for agricultural purposes because deep soils have higher moisture holding capacity and higher organic matter contents which has a positive relationship with soil nutrient content. Most native rangelands are on poor soils. It is therefore necessary that forage species selected for rangeland improvement must be able to do well on these relatively poor soils. The results of this trial showed that *C. rotundifolia* established better than the other two legumes on both the deep and shallow soils. Although *C. rotundifolia* and *C. pascuorum* are adapted to a wide range of soils they are best adapted to light textured surface soils (Skerman *et al*., 1988). *C. rotundifolia* has been reported to grow best on sandy soils of low fertility and has the ability to withstand grazing pressure and tolerate drought stress. Tarawali (1994) scored both *C. rotundifolia* and *S. hamata* high on yield and persistence in both sub-humid and semi-arid zones even in unweeded

fields. *C. pascuorum* is reported to give high dry matter yields in the semi-arid zone, but is not persistent.

## 5.4 FORAGE DRY MATTER YIELD

Forage yield data in this trial showed that dry matter yield of the native pasture was generally lowest at the beginning of the rainy season with a mean of 0.48 t DM / ha. As the rainy season progressed, the dry matter yield continued to build up and reached a peak of 6.0 t DM / ha by the end of rainy season (October). de Leeuw (1971) had earlier reported that growth starts after the first rains in April and is low until the end of May in this zone, thereafter it increases rapidly to a peak at the end of October, when most constituent grasses have finished flowering. Biomass accumulation between June and July was slow because most of the shoots were at seedling stages, but from August to October the materials were full grown with culms and tillers formed. Mean dry matter yields were below 0.5 t DM / ha in June and about 6.0 t DM/ha in October a period when all standing material had matured and attained highest dry matter content.

The dry matter yields recorded in this trial showed a mean yield of 5.8 t DM / ha across treatments compares favourably with what Agishi (1985a) reported for the same area. End-of-season yield of 2.0 – 3.0 t DM / ha had been reported on the upland site of the same area with higher yields on *Hyparrhenia rufa* dominant fadama grassland site (de Leeuw, 1971; Tanko, 1994). The dry matter yield recorded in the present study was considered good.

The effect of season shows that as the rainy season advanced, dry matter yield increased up to the end of the season. With the on-set of the dry season, dry matter yield began to

decline as the forage was being consumed by the grazing livestock, reaching its lowest point by the end of the dry season/beginning of the rainy season.

Dry matter yields in the unimproved treatment were higher than in all the strip-sown treatments. The legume content of the forage within legume strips, was higher in *C. rotundifolia* (48.0%) followed by *S. hamata* (41.0%) and lastly *C pascuorum* (19.5%). Both *S. hamata* and *C. rotundifolia* were not grazed in their fresh states in contrast to *C. pascuorum* which was observed to have been subjected to grazing by rodents right from germination to maturity. Even the pods that were being formed were eaten up. Thus, both dry matter yield and seed yield were suppressed. Oversowing the native pastures with legumes did not influence the annual total dry matter yields significantly ($P>0.05$) which is in agreement with Kusekwa *et al*., (1990). But both *S. hamata* and *C. rotundifolia* have the potential to contribute to the total dry matter production on rangeland. Barnes and Addo-Kwafo (1996) also reported that *C. rotundifolia* produced more dry matter in the dry season than the other legumes.

## 5.5 ANIMALS LIVEWEIGHT CHANGES

Weight responses to treatments showed that the grazing period of late dry season and the early rainy season animals on *C. pascuorum* and native pasture treatments lost weight while animals on *S. hamata* and *C. rotundifolia* treatments gained weight into the late dry season. The result obtained in this study followed the established pattern of weight changes in free range grazing animals on tropical rangelands which is a reflection of both the quality and quantity of available feed as reported by McCown *et al.,* (1981), McLennan *et al.,* (1988) and Holechek *et al*., (2004). The extension of the grazing period

recorded for *S. hamata* and *C. rotundifolia*, showed that the two legumes were able to sustain weight gains longer than *C. pascuorum* or the native pasture. The two legumes remained green longer into the dry season and were readily consumed to sustain the weight gains.

With the onset of the rains, there was a rapid increase in weight gain of the animals. This is perhaps a reflection of the quality of the forage and the principle of compensatory growth following a period of weight loss due to feed shortage. It is reported that cattle that had experienced a period of under-nutrition have higher than normal rates of weight gain when realimented (Richardson, 2009; Dixon, 2012). The amount of compensation when re-alimentation occurs, which is normally after the onset of the next rains, is dependent on the length of the underfeeding, the severity of the underfeeding and the amount of forage available in the re-alimentation period (O'Donovan, 1984; Matulis *et al.*, 1987; Ryan, 1990; Freking *et al.*, 2000). The rains resulted in a new flush of herbaceous vegetation which is usually higher in nutritive quality than what was available in the dry season. During the rainy season, liveweight gains of animals grazing oversown natural pastures or natural pasture alone usually do not differ (CSIRO, 1996) Kusekwa, *et al*. (1990) however reported a higher weight gain of 10% for animals on the oversown native pasture over those on the natural pasture alone. In this study it is shown that during the period of active growth animals grazing the native pastures compared favourably with those on strip-sown native pastures. Nonetheless, higher values were recorded for animals on the strip-sown than those on the native range pastures.

## 5.6 LEGUME PERSISTENCE AND SPREAD

Miller *et al*., (1988) has recommended *S. hamata* for strip sowing into native rangelands of Queensland, Australia because of its ability to spread fast, being a heavy seeder. In the present study, *C. rotundifolia* has outperformed *S. hamata* as it was observed to cross into adjacent paddocks. Its presence into other paddocks was noted as resulting from seeds having been carried by ants, water and shattering of the pods which scatters the seed far from the stands. *C. pascuorum* was virtually absent even on the strips where it had been sown. Tarawali (1994) had also reported the ability of both *S. hamata* and *C. rotundifolia* to persist but not *C. pascuorm*. From the result of this trial, *C. rotundifolia*, has proven to be capable of naturally spreading into native pastures very well even under the challenges of faster growing grasses.

# CHAPTER 6

# CONCLUSION AND RECOMMENDATIONS

## 6.1 Conclusion

The results of this trial showed that the three legumes tested were adapted to the environment of the Northern Guinea Savanna. They established well in the first year with *S. hamata* having the highest stand count followed by *Centrosema pascuorum* and lastly, *C. rotundifolia.* During the second year and the third year, *C. rotundifolia* overtook the other two legumes with *S. hamata* falling into the third position. This is associated with the seed production capacity of the three legumes. *C. rotundifolia* produced the most seed because it started seeding early in the rainy season and lasted into the early part of the dry season leading to very high soil seed bank from where the next season's seedlings recruitment took effect. The *S. hamata* and the *C. pascuorum* are also known to produce much seed but take a longer time to start seed production therefore the duration of seed production is rather shortened. The higher palatability of both the *S. hamata* and the *C. pascuorum* even when they are actively growing reduced their seed production capacity due to grazing, while *C. rotundifolia* was not grazed during the period of active growth and seed formation. The low palatability of *C. rotundifolia* in the rainy season gave it an advantage over the other legumes for seed production. *C. rotundifolia* proved to be capable of establishing well even on poor, infertile shallow soils which are the conditions found in most of the degraded rangelands.

Animals on *C. rotundifolia* and S. hamata were still gaining weight into the beginning of the late dry season while those on *C. pascuorum* treatment were losing weight. By the time the trial was assessed for legume spread into the surrounding native pasture *C. rotundifolia* was found to have penetrated deep into the grassy native pasture beyond its treatment paddocks.

## 6.2 Recommendation

From the foregoing, it is recommended that *C. rotundifolia* be adopted for the rehabilitation of most of the degraded rangelands in savanna ecological zones. Since *C. rotundifolia* is able to establish well even on poor shallow soils it can be used as the pioneer crop on such soils where it generates some vegetation cover during the rainy season which would create a modified micro-environment conducive for the establishment of other palatable plants. Its ability to spread fast enables early establishment of a mixed grass-legume combination which will raise the nutritional value of the available feed on the rangeland.

The mixture of the three legumes on a degraded rangeland will be an added advantage as the *S. hamata* and the *C. pascuorum* would provide some legume that could be grazed even during the rainy season while *C. rotundifolia* bulks up. The presence of the *C. rotundifolia* could provide some protection to the more palatable *S. hamata* and *C. pascuorum* from early grazing. This protection would allow the more palatable species to set seed for subsequent regeneration.

Re-seeded areas should be protected from grazing for one or two growing seasons following establishment. During that period, the end-of-year production could be harvested for stall feeding after seed shed. The subsequent rainy season, the pastures can be grazed early in the season to suppress the fast growing grasses while the legumes develop. At seed maturity in the early dry season, legume seeds would have dropped and animals can graze without effect on soil seed bank.

It is also recommended that a longer term evaluation of *C. rotundifolia* be conducted in some of the grazing reserves in the drier ecological zones of Nigeria.

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APPENDIX 1

BOTANICAL INVENTORY OF EXPERIMENTAL RANGE SITE TRIAL AT SHIKA

GRASSES

1. *Andropogon ascinioides*
2. *A. fastigiata*
3. *A. gayanus*
4. *A. schirensis*
5. *Brachiaria jubata*
6. *B. decumbens*
7. *B. humidicola*
8. *Chloris pilosa*
9. *Cteneum newtonii*
10. *Cymbopogon giganteus*
11. *Digitaria horizontalis*
12. *D. ternata*
13. *Elionurus purpurguinea*
14. *Hyperrhenia bagirmica*
15. *H. dissoluta*
16. *H. involucrate*
17. *H. rufa*
18. *Loudetia simplex*
19. *Monocymbium ceresiiforme*
20. *Panicum phragmitoides*
21. *Pennisetum pedicellatum*
22. *Pennisetum polystachyon*
23. *Rhottboelia exaltata*
24. *Schizachyrium sanguineum*
25. *Setaria anceps*
26. *Sprobolus pyramidalis*
27. *Urelytrum muricatum*
28 *Trachypogon spp.*
29 *Fimbristylis spp.*
30 *Hyparrhenia subplumosa*
31 *Microchloa spp.*

FORBS AND HERBS

32. *Acryranthes aspera*
33. *Adenodolichos paniculatus*
34. *Aspilia Africana*
35. *Borerria radiate*
36. *B. scabra*
37. *B. verticelata*
38. *Cassia mimosoides*
39. *C. nigricans*
40. *Cassia tora*
41. *Chamaecrista rotundifolia*
42. *Cochlospermum tinctorium*
43. *Commelina spp*
44. *Crotolaria retusa*
45. *C. macrocalyx*
46. *Desmodium velutinum*
47. *Dichrostachys cineria*
48. *Echinops longifolius*
49. *Hibiscus asper*
50. *Indigofera denderoides*
51. *I. pulchra*
52. *Ipomea aquatica*
53. *Lasiosiphon crausiana*
54. *Lippia chevoury*
55. *Monecma ciliatum*
56. *Schwenfurthia americana*
57. *Securidaca longipedunculata*
58. *Sesbania sesban*
59. *Sida alba*
60. *Sida linearis*
61. *Stylochiton lancifolia*
62. *Stylosanthes hamata*
63. *S. guianensis*
64. *Tephrosia bracteolate*
65. *T. linearis*
66. *T. pedicellata*
67. *Zornia glouchidiata*

SHRUBS

68. *Anona senegalensis*
69. *Detarium macrocarpum*
70. *Gardenia aquala*
71. *Guiera senegalensis*
72. *Hymenocardia acida*
73. *Isoberlinia doka*
74. *Kochia spp*
75. *Lophira lanceolata*
76. *Piliostigma thoningii*
77. *Terminalia avicenioides*
78. *Terminalia laxiflora*

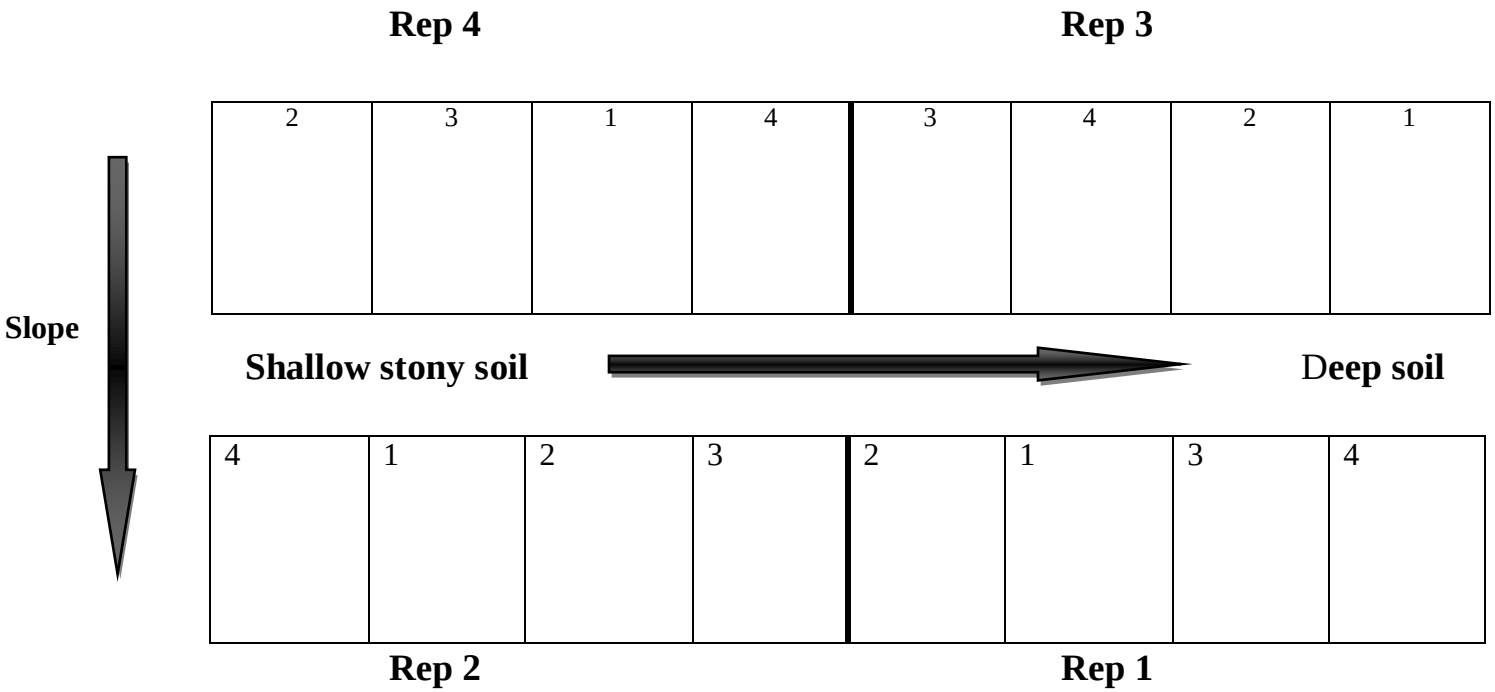
*79. Vitex diversifolia*

TREES

80. *Bridelia ferruginea*
*81. Butyrospermum paradoxum*
*82. Cussonia bateri*
*83 Ficus spp*
*84. Khaya senegalensis*
*85. Parkia biglobosa*

**APPENDIX 2:**

EXPERIMENTAL SITE LAYOUT.




Treatment keys

1. .*Stylosanthes hamata*
2. *Chamaecrista rotundifolia*
3. *Centrosema pascuorum*
4. Natural pasture (control)