IMPROVEMENT OF RANGELANDS BY OVERSOWING WITH LEGUMINOUS PLANT SPECIES IN SHINYANGA REGION, TANZANIA

BY

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ABSTRACT

Four herbaceous legumes (*C. pubescence, C. ternatea, M. atropurpureum and S. hamata*) were oversown in 1992 in Shinyanga, Tanzania to assess their effect on forage production quality and soil fertility. Forage and soil samples were taken in the seventh year of the experiment during the dry and wet season. Oversowing improved soil characteristics of Cation Exchange Capacity, organic matter content and available P. *C. ternatea, M. atropurpureum and S. hamata* persisted in the sword while *C. pubescence* virtually disappeared. In the dry season the CP content of the treatments in g/kg DM was 44.4, 37.6, 36.5, 35.0 and 29.7 for *C. ternatea, S. hamata, M. atropurpureum,* and *C. pubescence* oversown and the control treatments respectively. The DMD of the oversown treatments in g/kg DM was 384.4, 366.8, and 321.0 for treatments oversown with *C. ternatea, S. hamata* and *M. atropurpureum* in that order. OMD of the treatments in g/kg DM ranged from 304.4 to 425.2 for the control and *C. ternatea* oversown treatments respectively. The potential degradability of the treatments in g/ kg DM was 600.6, 585.1, 577.7, 572.9 and 492.0 for *C. ternatea, M. atropurpureum, S. hamata, and C. pubescence* oversown and the control treatments respectively. Biomass production results in t/ha were 1.75, 1.69, 1.66 and 1.62 t/ha for treatments oversown with *S. hamata, M atropurpureum, C. ternatea* and *C. pubescence* oversown treatments respectively. The control plots were significantly lower ($P<0.01$) in CP, potential degradability, DMD, OMD and biomass production than the oversown treatments.

In the wet season, natural pasture from the oversown treatments had significantly higher ($P<0.05$) CP content than the natural pasture of the control treatment. Natural

pasture associated with *C. ternatea*, *S. hamata* and *M. atropurpureum* had CP content of 55.3, 55.4 and 49.1 g/kg DM respectively. The control plots had 43.0 g/ kg DM. It was also found that mixed samples had better nutritional quality over the control. *C. ternatea, M atropurpureum* and *S. hamata* mixed samples had CP content of 68.8, 65.6, and 59.7 g/kg DM respectively. The control plots had CP content of 43.0 g/kg DM. The treatments had DMD of 478.3, 478.2, 447.3, 426.8 and 419.9 g/kg DM for *C. ternatea, M. atropurpureum, S. hamata and C. pubescence* over sown treatments and the control plots respectively. The OMD of the oversown treatments was 506.6, 493.9, 485.9 and 456.0 for *M. atropurpureum, C. ternatea, S. hamata* and *C. pubescence* respectively. The biomass production of the oversown treatments was 1.79, 1.70 and 1.62 for *S. hamata*, *M. atropurpureum* and *C. ternatea* oversown treatments respectively. The control treatment was significantly lower ($P<0.05$) in CP OMD and biomass production than the oversown treatments.

The CP content of the oversown legumes in g/kg DM was 151.9, 142.1 and 104.4 for *C. ternatea*, *M. atropurpureum*, and *S. hamata* respectively. The DMD of the oversown legumes was 534, 484 and 460 g/kg DM for *S. hamata*, *M. atropurpureum* and *C. ternatea* respectively. The OMD was 572.2, 547.8 and 512 g/kg DM for *S. hamata M. atropurpureum* and *C. ternatea* in that order. The potential degradability of the oversown legumes in g/kg DM was 570 for *S. hamata*, 718 for *M. atropurpureum* and 707 for *C. ternatea*.

C. ternatea, S. hamata and M. atropurpureum oversown treatments performed better than the other treatments in both the dry and wet seasons. *S. hamata* had excelled the other legumes in degradability and degradation characteristics.

From the results obtained it was concluded that oversowing legumes had improved soil fertility, biomass yield, nutritional quality and species composition of the rangeland.

DECLARATION

I, Mestawet Taye Asfaw, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and that it has never been submitted for a degree in any other University.

Signature: ....

Date ....7/11/2000...................

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DEDICATION

This work is dedicated to my beloved husband Solomon Tesfaye, Dr. Zinash Sileshi, and Mr. Alemayehu Konde and to my sweet mother Tsige Wolde, who supported, encouraged, wished and did everything she could ever do to see me succeed, and to my mother I say, 'Loving mum, Praise God, He has enabled me to get through'.

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LIST OF ABBREVIATIONS

ADF	Acid detergent fiber
ADL	Acid detergent lignin
CF	Crude fiber
CP	Crude protein
CPC	Crude protein content
CV	Coefficient of variation
DM	Dry matter
DMY	Dry matter yield
EE	Ether extract
FAO	Food and Agricultural Organization
g	Gram
ha	Hectare
ICRAF	International Center for Research in Agro-forestry
IVDM	*In vitro* dry matter
IVDMD	*In vitro* dry matter digestibility
IVOM	*In vitro* organic matter
kg	Kilogram
NDF	Neutral detergent fiber
NFE	Nitrogen free extractive
NORAD	Norwegian Agency for Development Cooperation
OM	Organic matter

CHAPTER I

1.0 INTRODUCTION

Most rangelands and pastoral livestock systems have suffered major land use changes through reduced availability, extreme climatic fluctuations, animal disease, demands from an increasingly important cash based economy and lack of motivation to improve the available resources (Roderick *et al.*, 1998). The changes that have occurred have influenced the way of life of the users in several ways. They were forced to practice continuous cultivation of the farmlands with shorter fallow periods, cultivation of more land to produce enough food, replacement of the traditional production systems, such as nomadism, to more sedentary forms of crop and livestock production and conversion of marginal lands to crop land which were meant for grazing (Powell and Williams, 1993). The continuous cultivation system has led to depletion of soil fertility and decline in crop production (Haan *et al.*, 1996; Brandstorm, 1985). The fast human population growth is driving up the amount of food that must be produced by the farmers resulting in increased deforestation (ILCA, 1993). Barnad (1964) points out that of all organisms affecting development and maintenance of grasslands, man has had the greatest influence both directly, through burning to destroy species, and indirectly through the management of animals.

The pastoral community culturally maximizes herd size aimed at minimizing risk associated with production from the rangelands (Roderick *et al.*, 1998) and as expression of social status (Nyamrunda, 1997). Therefore all cattle owners aim at herd size maximization, which puts high pressure on rangelands through overgrazing. The mismanagement of grazing animals can result in serious damage to the range ecosystem (Wilkinson, 1992). Overgrazing can destroy native vegetation, leading to the establishment of exotic species in their place, reduction of plant and animal bio-diversity and exposure of the soil to erosion (Haan *et al.*, 1996; Wilkinson, 1992). Oldeman *et al.* (1991) showed that overgrazing, agricultural activities and deforestation contributes to 35%, 28% and 37% of land degradation respectively. In most cases grazing lands are owned communally and therefore individual users have no motivation to conserve or improve it (Issae, 1997).

The above factors result in environmental degradation including soil fertility depletion, poor rangeland and animal productivity (Brandstrom, 1985; Haan *et al.*, 1996). Besides, the harsh climatic conditions often associated with rangelands, and shortage of rain makes the condition even worse especially in arid and semi-arid areas. However, the problem is more pronounced in the dry season when both quality and quantity of forage becomes low. Animals lose weight, reduce productivity and become easily susceptible to disease (Valentine, 1989).

Therefore the improvement and conservation of the deteriorating rangeland is of great importance (Otsyina *et al.*, 1996). Rangelands can be improved through different methods including range management, range seeding and range fertilizing, development of watering points and burning among others (Vallentine, 1989). In rangelands with poor soil fertility, poor bio-diversity, poor forage quality and quantity, introduction of technologies that can solve these problems is important. Because of its multiple purposes, introducing leguminous species is among the best options in improving rangelands (McDowell, 1972; Crowder and Chheda, 1982; Skerman *et al.*, 1988).

Shinyanga is one of the semiarid regions of Tanzania affected by problems related to rangelands. The problems are more serious during the dry season where both quality and quantity of animal feed is poor (Otsyina, 1993; Shem, 1995; Nyamrunda, 1997). An agropastoral tribe known as "Sukuma" inhabits the region. They have an indigenous knowledge of conserving feed, which is aimed at sustaining dry season forage supply for livestock. This system is referred to as *'Ngitile'*. Over years of continuous grazing, '*Ngitile*' have become poor in forage quality and productivity (Otsyina *et al.*, 1995). In order to improve the situation, ICRAF scientists have introduced different leguminous forage species (Otsyina *et al.*, 1997). *Centrosema pubescence*, *Stylosanthes hamata*, *Clitoria ternatea* and *Macroptilium atropurpureum* are among the herbaceous leguminous forage species that have been introduced to the area. These species were over-sown on the naturally exiting pasture, '*Ngitile*' seven years ago. Most work that have been done to evaluate the role of over-sowing legumes are conducted for short duration of time and they all base their recommendation on the results that are obtained from such conditions. However, these are not always indicative of performance to be expected over a long period of time. This study was therefore aimed at evaluating the influence of the introduced leguminous species on forage quality and quantity, their survival and composition in association with the natural pasture after a long period of over-sowing at Shinyanga region with the following objectives: -

1. To compare natural vs over-sown pasture in terms of chemical composition, degradability and yield.

2. To assess the quality of different species in the mixture.

3. To assess the composition and species ratio in the mixtures and determine appropriateness of different legumes for over-sowing.

4. To evaluate the effect of over-sowing leguminous plant species on soil fertility status.

CHAPTER II

2.0. LITERATURE REVIEW

2.1 Importance of rangelands

The major use of rangelands in the world is for livestock grazing (NRC, 1994). They are an important source of feed for both domestic and wild animals. About 135 million individuals, approximately 20% of the world's population, base their societies and economics on rangeland resources (NRC, 1990). They are essential and are also critical for maintaining an optimum energy cycle (Arjal, 1996). A tremendous amount of solar energy is trapped by range plants and changed to different cell components. These plants are then consumed by grazing livestock, and used metabolically. Man then harvests animal products. This basic pathway is critical not only for human survival but for preserving an eco-balance because energy in the form of foodstuff is continuously passed along the hierarchy (Paroda and Nal, 1995). They are also important for their products such as timber, medicinal plants, as a source of income from tourism and recreation (Kidunda, 1996).

2.2 Need for improving rangelands

The question of maintenance of rangeland resources and improvement of the conditions of rangelands is gaining much attention (Haan *et al.*, 1996). This is because of the pressure that has been put on the land by the rapidly growing human population and the associated development throughout the world (ILCA, 1993; Arjal, 1996). Deforestation, reduced soil fertility and productivity, declining forage quality and quantity and general environmental degradation are some of the major land use constraints that have resulted from this pressure (Mohamed-saleem and

Fitzhugh, 1993). In recent years, degradation has been intensifying. About 80% of the rangelands are moderately degraded. More than half of this area is located in the tropical and subtropical regions of the planet (NRC, 1990). These conditions directly influence animal productivity thereby affecting income and nutritional status of the family and national economy. From this, it is clear that a holistic management approach must be implemented to preserve the accelerating deterioration of this precious resource.

2.3 Different methods of improving rangelands

There are several ways of improving rangelands depending on the extent and stage of degradation, economic potential and management (Valentine, 1989; Arjal, 1996). Rangelands can be improved by direct or indirect means (Stoddart, 1975; Vallentine, 1989; Arjal, 1996). The direct ways include: range seeding, control of undesirable range plants, applying fertilizers and pitting, furrowing, and water spreading and the indirect means includes water development, fencing and trails.

In rangelands with poor biodiversity and poor soil fertility artificial reseeding is among the best solutions that help to enhance the growth of desirable species, improve feed quality and quantity and soil fertility (Heady, 1975). Particularly seeding rangelands with legumes can help to meet both soil fertility and forage quality and quantity improvement (McDowell, 1972; Haan *et al.*, 1996; Issae, 1997).

2.4 Dry season feed quality

The natural grasslands of warm climate presently provide poor grazing for ruminants

(McDowell, 1972; Küthe, 1976). The characteristic growth and development path for tropical grasses, including the rapid rise in lignin content with advancing age and the decline in digestibility as the plants mature, results in poor quality feed for grazing animals (McDonald *et al.*, 1995). A marked seasonal change in rainfall distribution as well as evapo-transpiration rates further complicates the problems and in this area the nutritive value of the pasture is either permanently or temporarily inadequate (McDowell, 1972). As physiological maturity of the plants proceeds, the leaf: stem ratio widens and nutritive value drops. Protein, minerals, rate of intake and digestibility declines progressively and fibrous cell-wall components and lignin tends to rise (Van Soest, 1994). In mature grasses protein content may declines to 3% or less (McDowell, 1972; Skerman, 1988). As a result bacterial activity in the rumen will be depressed and intake decline (Van Soest, 1994; McDonald *et al.*, 1995).

The low feeding value of many mature tropical pastures is due to restricted consumption imposed by sub-optimum nitrogen for the rumen flora especially during the dry season as a result of decrease in nutrient content (Vallentine, 1989; McDonalds et al., 1995). This leads to low intakes and digestibility and consequent losses in weight and reduced productive and reproductive ability by grazing animals (McDowell, 1972; Nyamrunda, 1997).

2.5 Digestibility and intake of tropical pasture

Digestibility is an important measure of the nutritive value of forages. It refers to the proportion of a food which is not excreted in the faeces and which is therefore, assumed to be absorbed by the animal (McDonald *et al.*, 1995). It can be measured by direct method (*in vivo)* or indirect laboratory estimation method (*in vitro*).

Tropical forages have a lower digestibility, with wider variation among species, as compared with temperate forages at all stages of growth (Van Soest, 1994). Dry matter digestibility of tropical grass was reported to range from 30 to 75% by Skerman and Riveros (1990). This is associated with high temperature and transpiration rate (Crowder and Chheda, 1982). Lower digestibility at higher temperature happens because of two reasons. High environmental temperature results in the increased lignifications of plant cell wall. High temperature also promotes more rapid metabolic activity, which decreases the pool of metabolites in the cellular contents resulting in conversion of photosynthetic products to structural component (Van Soest, 1994).

Digestibility of grass declines with advancing maturity. During early growth stages they are highly digestible (40 to 70 percent), but they decline sharply as the season advances to less than 40 percent (Crowder and Chheda, 1982, Van Soest, 1994). The decline in digestibility is not only because of change in chemical composition but also because of decline of digestibility of chemical component. It was reported that as pasture mature, digestibility generally falls at 0.1 to 0.2 percent per day resulting in decreased voluntary intake (Skerman, 1989).

Crude protein content in forages can have a significant effect on digestibility. When CP content is more than 7% digestibility does not appear to be affected. But when it is less than 7 % microbial activity in the rumen will be depressed by lack of nitrogen. This causes an incomplete utilization of structural carbohydrates in the ingested forage and a slow rate of passage of the digesta. Therefore, forage digestibility and voluntary intake are significantly reduced (Crowder and Chheda, 1982). The amount of lignin is reported to be the major cause of variation on digestibility of forage (Van Soest, 1994).

The total intake of nutrients of a grazing animal depends on the interaction between various factors such as available herbage as well as herbage allowance (Mannetje and Ebersohlu, 1980). Skerman and Riveros (1990) indicated the feed intake for tropical pasture to be about 24 g/kg $w^{0.75}$ per day for a mature grass and 100 g/kg $w^{0.75}$ per day for immature temperate pasture.

Intake and digestibility are also adversely affected when mineral content of plants drop below the level required for animal growth (Fonseca *et al.*, 1998). Thornton and Minson (1973b) cited by Crowder and Chheda, (1982) reported that DM digestibility of *Pangola* grass-legume pasture increased from 41.6 percent to 44.9 percent when phosphorous concentration increased from 0.11 to 0.15 percent. Ress and Minson (1979), also showed that dry matter digestibility of pen-fed sheep increased 2.1 percent and intake by 11.3 percent when calcium concentration of forage increased from 0.22 to 0.38 percent. In high weathered tropical soils forage have greater tendency to absorb large quantities of silica that depresses intake of the herbage, much in the same way as lignin (Van Soest and Jones, 1968).

2.6 Effect of climate on nutritive value of forages

In any region of the world a major problem associated with the development of livestock industries is the supply of feed (Payne, 1990). The nutrient content of forage is variable throughout the year because of variability in climatic conditions particularly in the tropics (McDowell, 1972; Payne, 1990). Forage plants are more nutritious in the wet than dry season. Most studies show that there is a positive correlation between rainfall and the CP, silica-free ash and NFE content of the forage, and an inverse relationship between the rainfall and CF content (Payne, 1990).

Climatic factors such as temperature has an influence and affects chemical composition of tropical feeds. High temperature results in rapid physiological maturation characterized by formation of high proportion of cell wall component (Van Soest, 1994). Nutrient absorption is also restricted under high moisture stress and high intensity induces rapid physiological maturity accompanied by the formation of highly lignified tissues (McDonald *et al.*, 1995). On many parts of the tropics under natural soil fertility conditions, and up to about two months of growth after the onset of rains the CP content in forage grass is well above seven percent. With un-interrupted growth due to high heat intensity, the grasses rapidly mature and CP content drops drastically reaching values of 4 to 6 percent after 3 to 5 months. During the dry months CP content often drops below 4 percent and in later parts of the season values of 1 to 2 percent are recorded (Crowder and Chheda, 1982).

2.7 Pasture dry matter yield, its importance and factors affecting it

Herbage yield of tropical plants are seasonal and closely follow the cyclic pattern of rainfall (Kidunda, 1996). Dry matter yield gives the actual biomass that an area can produce at a specific time. Dry matter determination involves cutting or clipping the sample from a known area, weighing fresh material from large plot and drying a sample of known fresh weight to constant weight. The dry weight of a sample from a given treatment is then used to calculate the production of dry matter per unit area.

The knowledge of yield or dry matter production helps to calculate the carrying capacity of an area or the number of animals that can be accommodated in a given area over a specified period of time. It also helps to estimate the amount of herbage consumed by grazing animals (Kidunda, 1996).

The type and distribution of tropical grasslands are largely determined by climate and its interaction with the soil. Precipitation is the most important climatic element that affects adaptation, growth and production of forage species although temperature and light do contribute too (McDowell, 1972; Kidunda, 1996). Any nutrient below the critical level in the soil would limit forage yield. Application of phosphorous and nitrogen in deficient soil will increase forage yield and their content in plant tissue. Cutting interval also affects biomass production. There is an increase in dry matter yield with extended cutting intervals. This is a consequence of additional litter and leaf formation, leaf elongation and stem development. However, more nutritious herbage is obtained with short cutting intervals. Cutting too frequently reduces total forage yields, depletes carbohydrate reserve, causes a decline in root development, favors weed invasion and adversely affects re-growth potential (Crowder and Chheda, 1982). Cutting near ground level increases total and seasonal forage production over a short period as compared to more elevated cutting heights, but plants are adversely affected in the same way as too frequent cutting (Crowder and Chheda, 1982).

2.8 Potential of legumes in improving rangeland condition and animal productivity

The most important role of legumes is fixation of atmospheric nitrogen by the symbiotically associated rhizobium bacteria species that lives on the root system of plants by forming nodules (Abubeker, 1997). The fixation of nitrogen helps in increased soil fertility and higher level of protein content of forage plants making them high in quality. Legumes have higher levels of protein in their earlier growth stage, which makes them remain high in their quality even during the late maturity stage as compared to grasses (Skerman, 1988). They play an important role in developing sustainable agriculture. Recently there is an increased effort in incorporating leguminous plant species in agricultural systems because of their multiple functions. They can be used as a source of mulch, green manure, supplementary browse and live fence (Kang and Duguma, 1985). Legumes can enhance soil biological activity by their residues and exudates, and pests and weeds can be influenced by the presence of legumes in the pasture e.g. the control of ticks with *Stylosanthes spp* (Sutherst *et al.*, 1982).

2.8.1 The role of legumes on soil fertility

Legumes increase soil organic matter content, cation exchange capacity (CEC), soil water holding capacity and reduced soil surface temperature (Molongoy and Kang, 1986; Tarawali et al., 1987). Research in Australia indicated that tropical legumes can fix 100 to 400 kg of nitrogen per ha annually (McDowell, 1972; Crowder and Chheda, 1982). Work by Wilson *et al.* (1982) showed increase in soil nitrogen content ranging from 0.01 to 0.06 percent over a two years period.

Skerman *et al.*, (1988) have shown the potential and importance of legumes in improving soil fertility, forage quality and quantity and animal productivity. In Sudan *Acacia senegal* on a gum-cropping cycle plays a role in soil fertility building (Skerman *et al.*, 1988). At Tanga Sisal Research Station, a cover crop of tropical Kudzu or Puero, *(Pueraria phaseoloides)* growing as an inter-row crop with sisal on a red loam soil over gneiss increased the yield of sisal by 48% above that of a clean-weeded, inter-row cultivated crop. In addition, it added 635kg of nitrogen/ha to the soil, which is equivalent to the application of 1.4 tones of urea/ha (Rijlebusch, 1967). At the end of the period the difference between the soil nitrogen under the cover and clean cultivated was 2195kg/ha (Skerman, 1988). After 74 months the soil organic carbon had increased from 1.85 to 2.96 percent under the *Pueraria* cover, and the total nitrogen from 0.163 to 0.248 percent.

Schofield (1945), cited by Skerman (1988) compared the nitrogen accession in the soil under a seven-month bare fallow with that added by ploughing in tropical legume after 18 months of growth. The nitrogen level in the soil under the bare fallow treatment was 34.4 ppm while that in legume-incorporated soil was 66.7 ppm for *Calopogonium mucunoides*, 71.7 ppm for *Centrosema pubescence*, 171.8 ppm for *Pueraria phaseoloides* and 54.4 ppm for *Stylosanthes guianensis*.

2.8.2 The role of legumes on forage production

The biomass production of forage legumes is generally lower than that of grasses (Skerman, 1988). Supporting this idea, Crowder and Chheda, (1982) indicated the annual dry matter yield of grasses as ranging between 0.5 t/ha on the arid *Aristida* native grasslands of the sub-Sahara to more than 100 t/ha on heavily fertilized *Pennisetum purpureum* planting in the humid, lowlands of the tropics and for legumes ranging between 9.9 to 34.6 t/ha.

Tothill (1986) reported that introduction of legumes in to the natural pasture can increase animal production up to ten times. Browse and legumes are generally richer in protein and minerals and contain twice the amount of energy in dry grasses (Shem, 1995). Legumes have great potential for enhancing grazing resources, largely because of their ability to provide a source of nitrogen to the associated grasses (McDowell, 1972; Whiteman, 1980; Crowder and Chheda, 1982). By fixing nitrogen legumes can enhance soil fertility and increase the yield of associated plants (MacColl, 1990; Tarawali, 1991) and provide high quality feed for livestock (Triphathi and Gill, 1981; Otsyina et al., 1987).

The nitrogen input helps alleviate the frequently limiting supplies of mineral nitrogen in tropical soils. The amount of minerals in fodder can also be greater with legume component in the pasture (Whiteman, 1980). This can be particularly important in environments where minerals can limit animal performance.

Other benefits from legumes include improved nutrient cycling via increased litter quality and greater amounts of nutrients passing through the animal (Floate, 1981; Vallis *et al.*, 1983). Their presence in a pasture usually contributes to the total nutritive value of the forage (McDowell, 1972).

2.8.3 The role of legumes on animal performance

Legumes are generally provided as a supplement with other feeds. This is because of their toxicity and existence of some anti-nutritional factors (Crowder and Chheda, 1982). In the dry season when animals feed on crop residues such as maize and sorghum stover, coffee hulls and other crop by products, supplementing the animals with forage legumes can increase the feeding value of the crop residue thereby increasing animal productivity (Toothill, 1986).

In Zaire traditional extensive system of livestock husbandry, using natural *Hyparrhenia* pasture burnt annually yielded only 10-15 kg/ha/year in live-weight gain in cattle while the improved practice (over-sowing with legumes) resulted in five times increment in production and gave a useful profit over expenditure (Skerman et al., 1988). In Nigeria, pasture of *Centrosema* and star grass raised live weight gain of cattle by 21% during the wet season and 50% during the dry season, over gains from grass alone (McDowell, 1972).

In a research conducted at the Serere Research Station, Uganda inclusion of *Centrosema pubescens* and *Stylosanthes guianensis* increased animal productivity by 11-49% (Skerman et al., 1988). Toothill, (1986) indicated that this method increased animal productivity by up to ten times. Research conducted at Bako Research Center, Ethiopia also showed that Horro bulls grazing on stylo over-sown natural pasture increased five fold live-weight as compared to animals grazing on pure natural pasture (Abubeker, 1997).

Stobbs (1969h) cited by Skerman, *et al.* (1988) obtained a live weight gain of 432 kg/ha/year from a *Panicum maximum/Macroptilium atropurpureum* pasture at Serere, Uganda. The inclusion of siratro in the mixture considerably extended the quality of the herbage during the dry season.

In Colombia, Savannah grass-legume pastures more than doubled animal live-weight gain per head and increased production on an area basis by ten fold compared with a managed native Savannah grassland. The grass/legume pastures increased live weight gain per head by 50% and per ha by 20-30% compared with the pure grass pasture. Increase of a similar order was obtained with grass/legume pastures on degraded rainforest lands (Thomas *et al.*, 1992). Recent results obtained with the forage legume *Arachis pintoi* associated with *Brachiaria spp* showed that animal live-weight gains of as high as 500 kg/ha/yr were possible on infertile oxisols (Lascano, 1993).

In a grazing trial under irrigation in the Burdekin delta in North Queensland, Australia, cattle averaged a daily live weight gain of 0.68 kg/day grazing on a para grass (*Brachiaria mutica*)/*Clitoria* pasture, a higher gain than from Stylo and Centro mixtures (FAO, 1994).

Benefits from legumes have been observed within the first year of grazing in an experiment comparing a grass-only pasture of *Brachiaria dictyoneura* and two grass-legume associations, *Brachiaria dictyoneura* with either *Centrosema acutifolium* or *Stylosanthes capitata* (Fisher *et al.*, 1993). The presence of either of the legumes more than doubled the animal live weight gains on a sandy oxisol compared with the grass-only pasture. The legume contents of these pastures were 29% for *C. acutifolium* and 31% for *Stylosanthes capitata* (Thomas and Lascano, 1995).

Significant increase in milk production in the order of 20% has been obtained on grass/legume pastures compared with improved grass only pasture. In a dairy farm of Coastal Queensland, over a five-year period production, milk butterfat increased from 64.1 to 111 kg/cow (Skerman *et al.,* 1988). These benefits, which can be attributed to the presence of a forage legume in the pasture, have been observed with a range of pastures with different legumes in different ecosystems of the region (CIAT, 1992)

At Ibadan, Nigeria, the milk production of white Fulani cows did not vary significantly (about 5.5 kg/head per day) when grazed on different mixtures of giant *Cynodon*, elephant grass and guinea grass in mixture with centro (Olaluku, 1972). Slight increase occurred when centro composition was more than 20% in the mix.

Slight increase occurred when centro composition was more than 20% in the mix.

Reproductive performance has also been improved with grass/legume pasture compared with a native savannah. The dates of first calving occurred 30% earlier and calving intervals were shortened by 22% in cows grazing on *Andropogon gayanus*/*Stylosanthes capitata* pasture compared with those grazing native grasslands (Skerman, 1988).

2.8.4 The role of legumes on chemical composition of feeds

Legumes improve the chemical composition of feeds when produced in a mixed sward. In Puerto Rico, the introduction of tropical Kudzu *(Pueraria phaseoloides)* in to a pasture of molasses grass *(Melinis minutiflora)* raised the protein level from 4.2% to 8% with 60% legume by weight in the mix (Vicente-chandler, Caro-costas and Figarella, 1953) cited by Skerman *et al.* (1988).

Over-sowing natural grasslands with leguminous species improves the yield and quality of herbage as well as performance of grazing animals. An experiment was conducted by Rukanda and Lwoga (1981) for six months by over-sowing *Macroptilium atropurpureum* and *Staylosanthes guyanensis* in *Themeda-Hyparrhenia* dominated natural grassland at the Faculty of Agriculture, Forestry and Veterinary Science, Morogoro. Then dairy heifers grazed the forage over a six months period. The results showed that over-sowing increased the total DM yield by 30% and CP by 50%. Similarly the mean CP content, over the six months, was increased by 12%, the mean *in vitro* DM digestibility by 7% and live-weight gain of heifers by 112%.

The problem with legumes use has been lack of persistence under grazing, which depends on the legume species and its acceptability. This can result in the legumes being grazed out of the pasture within a few years (Thomas and Lascano, 1993). However, if they are grazed in mature stage there is a possibility of seeding through faecal execration depending on the plant species.

2.9 Description of the over-sown legumes

2.9.1 *Centrosema pubescence*

Centrosema pubescence is a leafy, vigorous, low growing, trailing, twining and climbing perennial herb that is easily established from seed, regenerates freely and smothers weeds (McDowell, 1972). It is native to tropical South America and now widely grown throughout the tropics. It is a drought tolerant legume that grows in a range of soils. Persists well under grazing and can produce 4950 kg DM/ha/year (Skerman *et al.*, 1988). It can fix 100-135 kg nitrogen/ha/yr. It has CP content of between 16-19% of DM and grows very well in association with a number of grasses e.g. Molasses, Guinea, Napier and Para (Mcdowell, 1972).

2.9.2 *Clitoria ternatea*

Clitoria ternatea is a climbing legume, shrubby at base, summer growing perennial, and drought tolerant. *Clitoria ternatea* is palatable and is adapted to a wide range of soil conditions. It is native to tropical America, widely grown as an ornamental in the warmest parts of the world. Used for grazing and combines well with Sudan grass, sweet sorghum and specially sunn hemp. It has fast initial growth; up to 24 tones of fresh material per hectare obtained after only two months (FAO, 1994). DM yield varies under different conditions. In Zambia DM yield of 3330 kg/ha and 13350 kg/ha under irrigation and 1109 kg/ha under dry land were obtained (Skerman *et al.*, 1988).

Chemical composition of fresh arial part in Philippines was found to be 19.5% CP, 11.8% CF, 8.6% ash, 4.5% EE, 5.6% NFE and 3.29% Ca and 0.17% P (FAO, 1994). It was also indicated that the CP content of between 10.5-25.5% of DM could be obtained depending on the soil type, soil nutrient and some other factors (FAO 1994).

2.9.3 *Stylosanthes hamata*

Stylosanthes hamata, commonly known as stylo, is widely distributed in the tropical and subtropical environment (Costa, et al., 1991). It is native to Latin America (Mohlenbrock, 1963) cited by Abubeker (1997). *Stylosanthes hamata* is herbaceous annual to short-lived perennial plant. Mainly occurs in the West Indies in the Caribbean area generally and in coastal areas of Venezuela and Colombia bordering the Caribbean. It also occurs in the costal area of southern Florida in the United States. It is now grown as fodder bank in the tropical Africa (Skerman, 1988). It is a heat loving, drought tolerant, low altitude plant and suited to the infertile, acid and sandy-surfaced soil. Over-sowing in to natural pasture can give good result (Skerman *et al.*, 1988).

Clotti *et al.* (1999) found CP content of 8.5%, 0.17% Phosphorous and 1.16% potassium mean from three seasons. Forty stylo accession were evaluated for a series of agronomic characteristics at one 120d and 60d harvest, the average DM yield (DMY), crude protein concentration (CPC) and *in vitro* DM digestibility (IVDMD) of the 120 days stylos were 2695 kg/ha, 17.3% and 52.7% respectively. Across the four-60d harvest, the DMY, CPC and IVDMD were 1563 kg/ha, 16.4% and 52.4% respectively (FAO, 1995). In India dry matter yield of 7.23-10 t/ha/year was reported by Gill and Patil, (1985a) and in Ghana DM yield of 1.0-1.2 t/ha/year was reported by Barners and Abdo-Kwafo (1996). CP content was reported by Malcala and Kiflewahid (1996) to be greater than 10%. Skerman (1988) found in vitro dry matter and organic matter digestibility of 60 to 65 percent respectively.

2.9.4 *Macroptilium atropurpureum*

Macroptilium atropurpureum also called siratro is a deep-rooting perennial with trailing pubescent stems which may root anywhere along its length, especially in most clay soils. It naturally occurs in Central and South America. Siratro is a summer-growing plant with greatest growth in mid-summer to autumn in South Queensland. Usually sown together with grass or used to over-sow natural grassland. Maximum DM was produced at 30/25°C and 27/22°C in a long day (Skerman *et al.*, 1988). It is extremely drought-tolerant, thrives on a wide range of soils except the poorly drained ones (Davies and Hutton, 1970) cited by Skerman *et al.*, (1988). It can fix 175 kg N/ha/year. It should be grazed lightly at all time. Milford, (1967) cited by Skerman *et al.* (1988) determined the chemical composition and obtained 35% DM, 16.8% CP, 1.2% EE and 9.8% ash. The *In vitro* digestibility result of DM

50.4%, OM 53.4% and CP 67.6% were given by FAO (1994). Crude protein digestibility on sheep was also found to be 82.9%, (FAO. 1994). The chemical composition of *Macroptilium atropurpureum* as described by FAO is presented in Table 1.

Table 1: The Chemical composition of *Macroptilium atropurpureum* at different stages of growth.

	DM	CP	CF	Ash	EE	NFE	Ca
20 weeks	29.2	11.5	36.6	5.9	2.2	43.8	0.64
16 weeks	26.6	14.3	35.5	6.2	2.6	41.4	0.70
13 weeks	23.6	15.5	34.7	6.6	2.9	40.5	0.78
11 weeks	21.6	16.5	33.6	7.6	7.8	39.5	0.85
8 weeks	19.8	17.7	27.7	7.2	2.6	44.8	0.80

Source: FAO (1994).

FAO (1994) gave the analysis of mature siratro at the seed- shading stage, leafy but 20-30% of the leaf dry. He found 35% DM, 16.8% CP, 33.4% CF, 1.2% EE; 38.8% NFE and 9.8% ash.

2.10 Rangeland deterioration in Shinyanga

Shinyanga is one of the semi-arid regions of Tanzania located in the Northwest part of the country. There exist an agro-pastoral tribe called Wasukuma (Brandstorm, 1985). The "Wasukuma" live on close integration of both crop and livestock production also called mixed farming system (Haan *et al.*, 1996).

Shinyanga is one of the most deforested regions of Tanzania (Leach and Mearns, 1988) cited by Msangi (1995). The rangelands are deteriorated and nearly 85% of the region is now dry, open and degraded.

Possible reasons for rangeland degradation in the region includes:

- Massive tree cutting program to eradicate tsetse flies (Barrow *et al.*, 1988).
- Forest clearing for agricultural activity and firewood (Msangi, 1995).
- Increasing herd size feeding on diminishing and less productive range land (Msangi, 1995; Issae, 1997; Nyamrunda, 1997)
- Increased demand for cultivatable land as a result of increasing human population and due to one main out let for cash occurring through cotton sale (Msangi, 1995; Otsyina *et al.*, 1996).
- The villagelization act of 1975 (Msangi, 1995).

Because of the above factors environmental degradation and deforestation have gone in the region at an alarming rate resulting in decline in soil fertility, poor forage quality and quantity, soil erosion, wind cyclones and other problems (Regional Profile, 1996) and as a result today the region is supporting much impoverished vegetation (Msangi, 1995). Animal production is thus affected greatly, especially during the dry season (Otsyina, *et al.*, 1995).

2.11 Traditional forage conservation system

The Sukuma agro-pastoralists have developed and used fodder conservation system known as '*Ngitile*'. The term '*Ngitile*' comes from the sukuma word which means "a reserve" (Msangi, 1995). '*Ngitile*' are demarcated fallow pasture plots as a means of conserving fodder in form of standing hay in Sukuma communities (Nyamurunda, 1997). The system is developed in response to severe dry season fodder shortage, overgrazing, land degradation and scarcity of building materials (Bradstrom, 1985). The '*Ngitile*' system has been popular among the Wasukuma in Shinyanga region since the 1920s and 1930s (Brandstorm, 1985, Otsyina and Asenga, 1993). Each cattle owner at that time, reserved grassland in fallow partly to support thatching grass but mainly for cattle reserve or pasture (Msangi, 1995). Though the system broke down with the introduction of the villagelization concept in 1975, the knowledge still exists among the "Wasukumas" (Barrow *et al.*, 1988).

'*Ngitile*' are owned both communally and privately (Issae, 1997). Communal '*Ngitile*' range between 5 and 3000 ha with an average size of 353.1 ha and private '*Ngitile*' range between 0.2-250 ha with an average of 12.8 ha. Grazing on '*Ngitile* start between the month of August and September and ends between November and December when ample fodder becomes available in non-*Ngitile* areas (Issae, 1997). Biomass production has been found to be 3420 kg/ha only sufficient to stock 1.5 LU/year (Otsyina et al., 1996). Biomass production varies with season, the dry season being the most critical period. All types of animals graze '*Ngitile*'; however, this depends on the size of the *Ngitile* and feed scarcity (Rubanza, 1999). Priority is given to oxen, milking cows, calves and sick animals (Otsyina and Asenga, 1993).

'*Ngitile*' are low in productivity because of overgrazing, and poor quality forage species composition (Issae, 1997). They are therefore not fully exploited. The grasses flourish during the wet season, but easily disappear during the dry months. The plant communities on *Ngitile* are composed of 89.5% grasses 6.4% forbs and

4.1 % trees (Issae, 1997). *Hyperrhenia rufa* is the dominant grass species. It is a highly productive fodder but low in quality. Bogdan (1977) cited by Issae (1997) reported low crude protein content (1.4%) during the dry season. This is the season when *Ngitile* are generally grazed.

The system is constrained by insecurity due to lack of proper land tenure systems, over use of grazing lands, lack of fertilizer application and low fodder quality (Nyamrunda, 1997).

2.12 Animal husbandry and land use system

Livestock contribute greatly to the socio-economic welfare of the Sukuma people who are traditionally cattle keepers. The animals are socially valued as a symbol of status, security, for dowry payment, for their products and purchase of basic needs (Issae, 1997; Nyamrunda, 1997). It is the second dominant economic activity in the region. It is estimated that 20% to 30% of the total livestock population of the country is found in Shinyanga region (Regional profile, 1996). Livestock are extensively reared on open communal or private grazing lands although a few are occasionally tethered. Dry season supplementation is only practiced on a few dairy farms in town ships and on draught oxen in some districts. Common supplements include maize and sorghum stover, hay, rice straws, cotton hulls, cotton seed cake, maize bran and rice polishings.

Some of the Wasukuma livestock keepers still practice semi-nomadic life and about 1% move to central and south of the country out of the region annually because of land constraints and drought (Regional profile, 1996). According to livestock census conducted country wide in 1984, the livestock growth rate in the region was estimated at 1.6%/annum (Nyamrunda, 1997).

Livestock population according to the 1988 actual count and 1995 sample census is indicated in Table 2.

Table 2: Livestock population of Shinyanga Region for 1984 and 1995.

Type	Actual count (1984)	Sample census (1995)
Cattle	1,916,749	2,262,809
Goats	1,077,986	1,187,706
Sheep	455,145	488,267
Donkeys	11,487	22,639
Pigs	618	2,639
Chicken	953,613	2,768,913
Rabbits	637	? *

* Number was not available

Source: Regional Livestock office, Shinyanga and Bureau of statistics, Dar-es-Salaam.

Livestock numbers are considerably high and they have been maintained for the last three decades despite the natural and other problems facing this production sector (Nyamrunda, 1997). About 80% of the people own livestock with herd size ranging between 5-1000, with an average of 50 (Issae, 1997). Livestock population in the region is estimated at 1,916,749 (cattle) and the available land is about 950,000 ha. Thus cattle to land ratio is 2:1. Considering the fact that an animal unit requires about 2ha/year, it is obvious that the land is overstocked (Nyamrunda, 1997).

Sale of livestock and livestock products is the second source of income next to cotton (Msangi, 1995). Animals also contribute to the national economy *e.g.* in some districts livestock levies and fees constitute up to 25% of the Region's GDP (Nyamrunda, 1997)

Table 3 shows the region land use system. The agricultural potential land is estimated at 2,193,500 km^2, which is about 46% of the total area. The grazing land covers 950,000 km^2 that is estimated at 19 % of the total area. The forestland and game reserves, which are about 33 % of the total area, can also provide additional feed source for the livestock.

Table 3: Shinyanga region land use 1994.

The regional land use	km^2	Percent
Agriculture potential land	2,193,500	46
Grazing land	950,000	18
Game reserves	987,000	19
Forest land	704,200	14
Rocky hills, lacks, rivers etc	146,400	3
Total area	5,078,100	100

Source: Shinyanga Regional Planning office- 1994

CHAPTER III

3.0 MATERIALS AND METHODS

3.1 Description of the study area

The study was conducted at ICRAF, Lubaga research site in Shinyanga Region.

3.1.1 Location, area and human population

Shinyanga is located in the northwest part of Tanzania and makes part of the Lake Zone (Regional profile, 1996). It forms part of what is used to be known as Sukuma land. The region is located between latitude 2^0 and 5^0 south and longitude 31^0 and 35^0 east (Issae, 1997). The altitude of the area varies between 1000-1500 meters above sea level (Otsyina and Asenga, 1993).

Shinyanga region has a total area of 5,075,100 km^2. This makes it the ninth largest region in the country (Regional Profile, 1996).

Shinyanga is a moderately populated region. It has the second largest population in the country (Bureau of Statistic, 1996). Human population, according to the 1988 census was 1,763,960 with 2.9% growth rate. Population density was estimated at 34.74 people per km^2. The number of households was 279,690 with average household size of 6.3 (Population census, 1988). The present population is estimated at 2 million.

3.1.2 Topography and Vegetation

The topography of the region is characterized by low lands (Mbuga flats), gently undulating plains with low ridges, rocky out crops and small hills scattered throughout (Heemstra, 1992) and covered with sparse vegetation (Regional Profile, 1996).

Vegetation is mainly open bush savannah grassland with few *Acacia* and baobab (*Adansonia digitata*) trees (Nyamrunda, 1997). The northwest and northeastern part of the Region are covered by natural forests, which are mainly Miombo woodland (Regional Profile, 1996). The vegetation consists of grasslands, wooded grasslands and bushed grassland (Herlocker, 1973).

The dominant grasses are *Hyperrhenia rufa*, *Eragrostis superba*, *Heteropogon contortus*, *Chloris roxburghiana*, *Cynodon dactylon*, *Aristida asscensionis*, *Dichanthium annulatum* and *Rynchelytrum ripens*. Associated forbs and trees are *Tephrosia pumila*, *Tridax procumbens*, *Hygrophila acoriculata*, *Stylosamthes fruticosa*, *Acacia nilotica*, *Acacia polyacantha*, *A. senegal* and *A. tortilis* (Issae, 1997). Sub-dominat forbs found were *Tridax procumber* and *Conyza*.

3.1.3 Climate

Shinyanga region has a tropical type of climate with clearly distinguished rainy and dry seasons. The region receives an annual rainfall of about 600-900 mm between November and May but is usually erratic, unreliable, and poorly distributed (Otsyina, 1993; Nyamrunda, 1997). Normally it has two peak seasons (Regional profile, 1996). The first peak lies between mid-October and December, while the second one, the longer season, falls between December and mid May (Msangi, 1996). The dry season begins in mid-May and ends in mid-October. The dry season is the worst period for the region (Regional profile, 1996). The soil becomes hard to cultivate, pasture becomes very poor and availability of water for domestic use and livestock becomes acute (Issae, 1997).

Monthly temperatures vary from 27.6°C to 30.2°C (maximum) and 15°C to 18.3°C (minimum) with an evapo-transpiration rate of 6mm per day that exceeds monthly rainfall almost every month, thus resulting in serious moisture deficits throughout the year (Getahun, 1992; Shem, 1995; Otsyina et al., 1995).

3.1.4 Soils

Soils are mainly black clays (cambi-soils and verti-soils) (Nyamrunda, 1997) locally known as "mbuga" and clay loam soils known as "ibushi" (Issae, 1997). The soils are distributed as a series of catena in which relief, geology and drainage interrelate to produce predictable soil sequence (Heemstra, 1992). Thus there is granite outcrop at the top of the slope, hills and hardpan soils and flood plains at the bottom consisting of black clays "mbuga soils" (Issae, 1997).

3.1.5 Agriculture

The average farm size per household is estimated at 3.2 ha (Regional profile, 1996). The main cash crops grown are maize, paddy, millet, sorghum, cassava, beans, sweet potatoes and groundnuts (Msangi, 1995). Livestock reared include the indigenous Short Horn Zebu cattle, sheep and goats, donkeys, pigs, rabbits and poultry (Issae, 1997). Besides agriculture and livestock keeping, mining and industrial activities play an important role in the economy of the region (Regional profile, 1996).

3.2 The studied species

Species that were studied includes the natural pasture, natural pasture over-sown with *Centrosema pubescence*, *Stylosanthes hamata*, *Clitoria ternatea* and *Macroptilium atropurpureum.*

3.3 Forage sampling and sample preparation

3.3.1 Sampling

3.3.1.1 Dry season forage sampling

The improved forage legumes were over-sown (by broadcasting) on the natural pasture seven years ago. The over-sown and the control (which was demarcated at the beginning of this study) plots were sampled in October 1999 to assess the nutritional quality of the forage during the dry season. During sampling a 0.25 m^2 metal quadrat was used. By then it was not possible to identify the different species in the mix as most of them had shaded off their leaves. Therefore, only one type of sample was taken from each plot. Three transects were made during sampling and from first and second transect (the diagonal ones) two quadrats and from the third transect the second quadrat were clipped. Then all quadrats from each plot were made into composite samples and subsamples were taken for further analysis. After sampling the plots were mowed to allow regeneration.

3.3.1.2 Wet season sampling

Wet season forage samples were taken in the first week of March 2000. Forage sampling was done on three transects in each plot by using a $0.25m^2$ metal quadrat. Quadrat throws were made at 5 meters interval on each transect. After throwing the quadrat, percent ground cover and composition of different species in the mix was estimated. On the first and second transect second and third quadrat and on the third transect second quadrat were clipped. This was done to reduce the border effects. Total quadrats clipped from each plot were five. From each plot three different types of samples were taken. These were grass (natural pasture) and legume mixed, legumes alone and grass (natural pasture) alone. After clipping the samples were kept in plastic bags and brought to the laboratory in a cool box.

3.3.2 Sample preparation

Fresh samples brought from the field were weighed in a paper bag and dried in an oven at 60^oC for 48 hrs. DM yield for both mixed and separate samples were determined by the difference between the fresh and dry weights. Dried samples from dry and wet seasons were ground to pass through a 0.2 mm sieve and kept in sealed bottles for further analysis.

3.4 Sample analysis

3.4.1 Determination of chemical composition

Samples of the experimental plants were analyzed for CP, EE, and Ash using proximate analysis method. The CP content was determined at ICRAF-Lubaga Research Center by Macro-Kjedahl method according to AOAC (1990) specification. EE content of the samples was determined by the Soxhlet's ether extraction apparatus in which the dried sample was put in a thimble and extracted by petroleum ether as described by AOAC (1990). The EE and ash content of the feed samples were determined at SUA.

The cell wall component which included neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined at ICRAF-Lubaga research center according to the Goering and Van Soest (1991) procedure using ANKOM200/220 FIBER ANALYZER.

3.4.2 Digestibility and Degradability

3.4.2.1 Digestibility

Sample dry matter and organic matter digestibility were determined at SUA by two stage *in vitro* digestibility technique as outlined by Tilley and Terry (1963).

3.4.2.2 Degradability study

3.4.2.2.1 Experimental animals and feed

Three cows fitted with permanent ruminal cannula from Magadu dairy research farm SUA were used. The cows were provided with 7 kg of hay and 3.5 kg of concentrate (2/3 maize bran and 1/3 cotton seed cake). The cows were housed in separate stalls and were all stall-fed.

3.4.2.2.2 Dry matter degradability

The rate of disappearance and degradability of DM of the samples was determined using the nylon bag technique as described by Ørskov et al. (1988). Approximately 1g of ground sample was put in nylon bags then tied with rubber band and fixed on the string in duplicate. Then strings were inserted in to the rumen of each cow and were removed after 6, 12, 24, 48, 72, 96 and 120 hrs. One set of bags for each sample were also prepared and washed immediately to determine the soluble fraction which represented the 0 hour. The experiment was done in four periods each of five days duration. In each period, four samples in duplicate were incubated in each cow. For each of the incubation time there were two observations per sample per cow, which made six observations in total. After removal from the rumen the bags were washed (using tape water and then with a washing machine), transferred to a filter paper and dried in an oven at 60°C for 48 hrs.

The proportion of DM degraded after each time interval, for each sample was calculated for each bag. The results from each set of the two bags from each cow gave an average value for DM degraded per cow, which gave three observations per sample for specific incubation hours. The proportion of DM degraded at each time interval was then calculated for each of the three cows using the following formula: -

$$\%DM\ deg = \frac{DM\ incubated - DM\ residue * 100}{DM\ incubated}$$

Degradability constant and fitted degradability values were obtained by fitting the results from DM disappearance to an exponential equation of the form: $P = a + b\ (1\text{-}e^{-ct})$ using "NAWAY" statistical package.

Where: a, b, and c are degradation constants (Ørskov and McDonald, 1979)

P = Percent degradability at time t.

a = Immediate degradable fraction (assumed to be disappeared immediately).

b = The insoluble but potential degradable fraction

$a + b$ = Potential rumen degradable material or the asymptote of the equation.

c = The fractional rate constant at which the fraction described by b is degraded.

t = Time

3.5 Soil sampling and analysis

3.5.1 Soil sampling

Soil samples from different treatment plots were taken using 5 cm diameter auger. From each plot 10 points were sampled and made into composite sample immediately. Soil sampling was done from two depths, 0-15 cm and 15-30 cm. Then the composite soil samples were kept in plastic containers for further analysis.

3.5.2 Soil sample analysis

Soil samples were analyzed for total nitrogen, extractable phosphorous, pH, organic matter, cation exchange capacity, extractable cation and particle size. Total nitrogen and organic matter content of the soil were determined at ICRAF-Lubaga laboratory while the other parameters were analyzed at SUA.

Total nitrogen was determined using Kjeldahl procedure outlined by Bremner and

Mulvaney (1982). Extractable phosphorous was determined by Bray and Kurtz 1 method as described by Oslen and Sommers (1982). Soil pH was analyzed by glass electrode method (McLean, 1982) using a solution of 1:2.5 soil-water and soil-potassium chloride. Percent organic matter was obtained by determining the organic carbon by the Walkley and Black wet digestion (potassium dichromate) method (Nelson and Sommers, 1982) and then by multiplying the value by the Van Bremmelen factor of 1.724. Cation exchange capacity was measured using neutral ammonium acetate percolation at pH 7 and titration with sulfuric acid (Rhoades, 1982). Extractable cation, (calcium, potassium, sodium and magnesium) content was determined by spectrophotometry or atomic absorption method (Thomas, 1982). Particle size was determined using the hydrometer method (Gee and Bauder, 1986). Soil moisture and bulk density was obtained by gravimetric method.

3.6 Experimental design and Method of data analysis

3.6.1 Experimental design

The over-sown leguminous plant species were established in a completely randomized block design. The experiment had four blocks with 4 plots. The four over-sown leguminous species were replicated four times, once in each block. The experimental design did not have a control plot. Therefore one block of 4 control plots was demarcated at the beginning of this experiment. Then the plots were randomly assigned to each of the other four blocks, which made a total of 20 plots. The plot size was 12m * 12m.

3.6.2 Data analysis

The data was analyzed using SAS (1998) statistical package. Means of chemical composition and yield were compared using List Significance Difference (LSD) test.

The following model was used in data analysis.

$$Y_{ij} = \mu + T_I + B_j + e_{ijk}$$

Where

Y_{ij}: chemical composition or yield

μ: Overall mean

T_i: Effect of i^{th} treatment

B_j: Effect of j^{th} block

e_{ijk} : Random error

For *in sacco* dry matter degradability, the samples were incubated in the rumen of three cows in a complete randomized design. Therefore the following statistical model was used.

$$Y_{ij} = \mu + T_I + e_{ij}$$

Where

Y_{ij}: DM degradability

μ: Overall mean

T_i: Effect of i^{th} treatment

e_{ij} : Random error

CHAPTER IV

4.0 RESULTS

4.1 General observations

Among the four oversown legume species *Centrosema pubescence* had disappeared from the field. On the other hand *Macroptilium atropurpureum* appeared in almost all bordering plots. It was also observed that the oversown treatments had higher numbers of species than the control treatment. Appendix 1 lists the species found on both oversown and the control treatments. The number of species on the oversown treatments was 43 while that of the control was 18. In the dry season it was not possible to separate the legumes from the grasses as they had shaded off their leaves.

4.2 Physical and chemical properties of the Soil

Table 4 presents the soil physical and chemical properties. Data for 1991 soil analysis were obtained from Otsyina and Asenga (1993). There was no difference in soil texture class, exchangeable potassium and exchangeable calcium content of soil before and after the experiment. The soil pH had changed from mildly alkaline to moderately alkaline. Total nitrogen increased from low to medium; organic carbon, exchangeable sodium and cation exchange capacity from medium to high and available phosphorous and magnesium from medium to very high.

Table 4: Soil physical and chemical characteristics of the research site for the year 1991 and 2000

Characteristics	1991[1]		2000		Remark
	Composition	Classification[2]	Composition	Classification[3]	
Texture (%)					
Sand	58.9		62.51		
Silt	12.9		12.9		
Clay	34	Sandy clay loam	27.91	Sandy clay loam	NS
Soil pH					
In water	7.7	Mildly alkaline	8.01	Moderately alkaline	*
In potassium chloride	6.7		7.03		
Organic carbon	2.2	Medium	3.41	High	*
Total nitrogen (%)	0.2	Low	0.26	Medium	*
Available P (ppm)	7.2	Medium	84.88	Rich/Very high	**
Exchangeable cations					
Na	0.6	Medium	1.3	High	*
K	0.6	High	0.45	High	NS
Ca	24.6	Very high	29.82	Very high	NS
Mg	3.6	Medium	2.93	Very high	*
CEC	23.5	Medium	25.72	High	*

NS= Non significant ($P>0.05$)

*= Significant ($P<0.05$)

**= Significant ($P<0.01$)

[1] Source: Otsyina and Asenga (1993).

[2] Was not indicated in the reference.

[3] Classification was made according to Landon (1991).

From the results presented, it was observed that legumes had improved the soil fertility status. Total nitrogen, organic carbon, exchangeable cation and cation exchange capacity had increased as compared to the initial soil analysis results.

4.3 Rainfall pattern of the study area

The rainfall pattern for the last ten years is indicated in Figure 1. The total rainfall was higher for 1994/95 and 1997/98. In the last 10 years the lowest annual rainfall was recorded for 1995/96 and 1999/2000. Therefore the lower biomass yield obtained for these years could be explained by this factor.

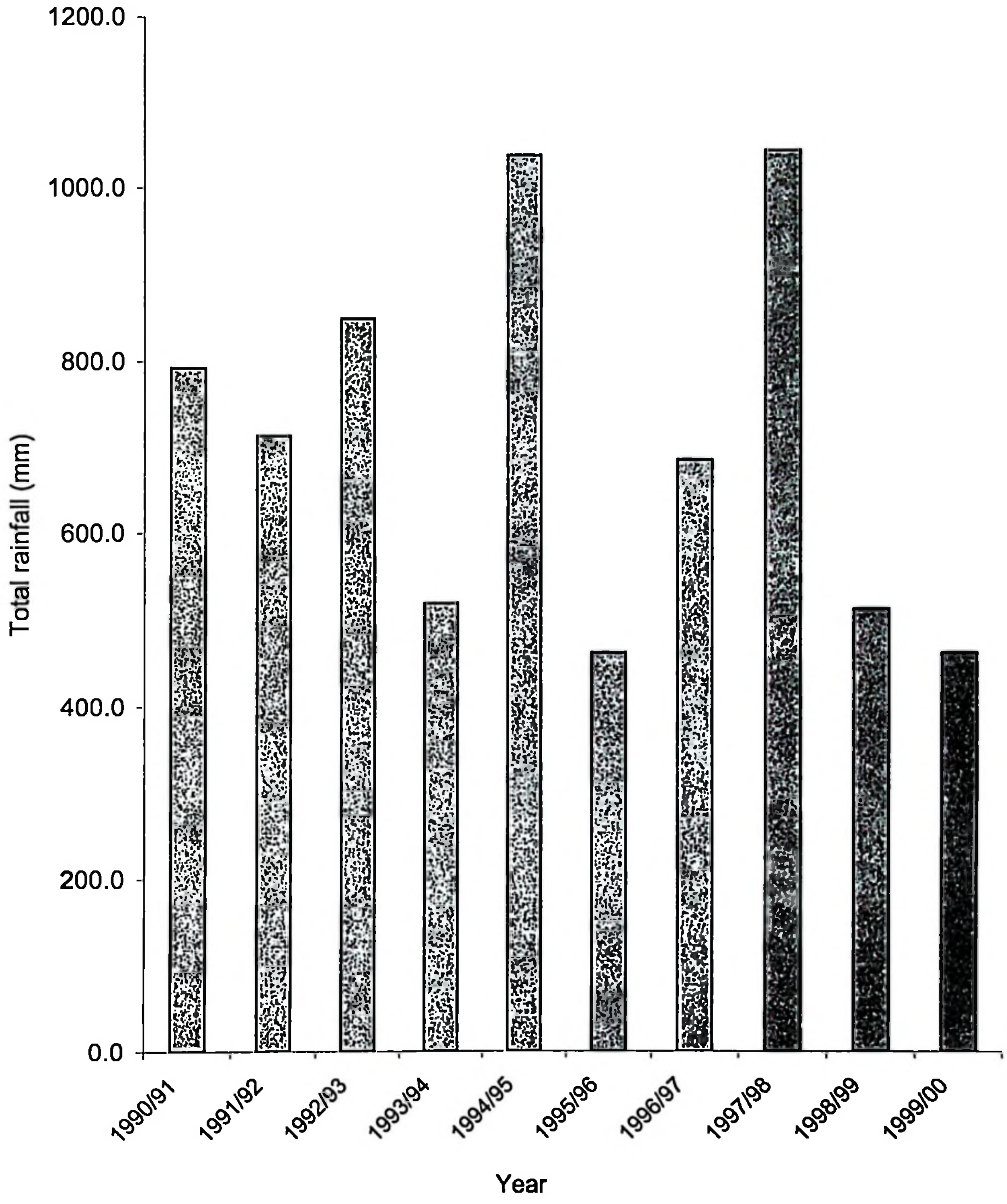

Figure 1: Rainfall pattern of the study area from 1991 to 2000

4.4 Biomass production

Biomass production for different years is indicated in Figure 2. Data for 1992, 1998 and 1999 were obtained from the research station records. In 1992, the biomass production of the treatments was lower as compared to the other years. In the same year, treatments oversown with *S hamata* had higher yield than the other treatments. In 1998, *C pubescence* oversown treatment had higher biomass production than the rest of the treatments. Though statistically not significant the wet season biomass production was higher than the dry season yield except for *C. ternatea* oversown treatment.

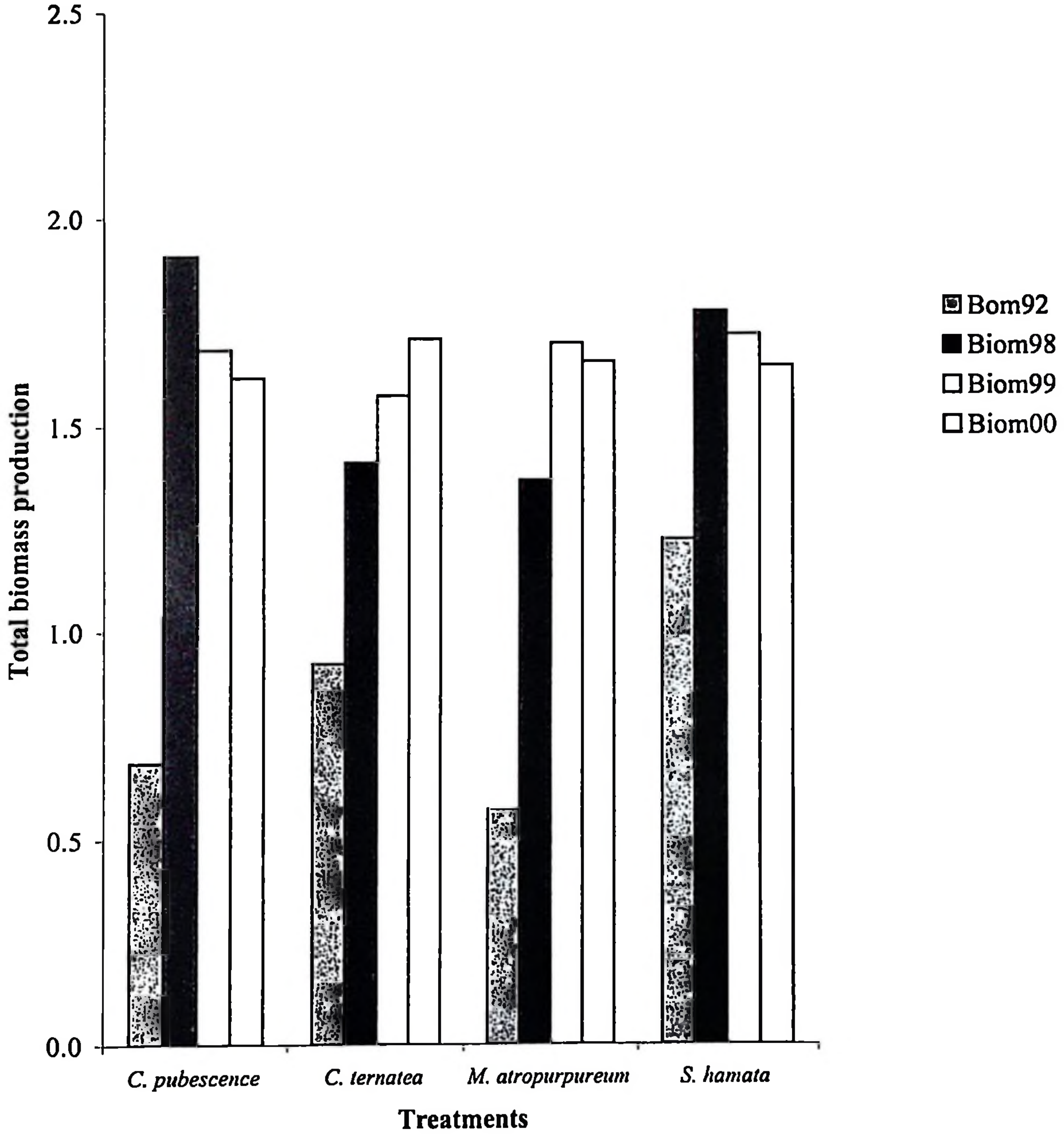

Figure 2: Biomass production for the natural pasture oversown with different legume species over years

Table 5 presents biomass production for the dry and wet seasons. The biomass available in the dry season ranged from 0.94 t/ha for the control treatment to 1.75 t/ha for the *S. hamata* oversown treatment. In the wet season it ranged from 1.25 t/ha to 1.79 t/ha for the control and *S. hamata* oversown treatments respectively. For both the dry and wet seasons the control treatment had significantly lower (P<0.05) biomass production than the rest of the treatments. The other treatments were not significantly different in biomass available (P>0.05) for both the dry and wet seasons.

Table 5: Seasonal biomass production at ICRAF-Lubaga Research site, in Shinyanga Region.

Treatments	Season		Remarks
	Dry (t/ha)	Wet (t/ha)	
Natural + CEPU*	1.62 ± 0.06^{a}	1.51 ± 0.11^{ab}	NS
Natural + STHA	1.75 ± 0.06^{a}	1.79 ± 0.11^{a}	NS
Natural + MAAT	1.69 ± 0.06^{a}	1.70 ± 0.11^{a}	NS
Natural + CLTE	1.66 ± 0.06^{a}	1.62 ± 0.11^{a}	NS
Natural pasture	0.94 ± 0.06^{b}	1.25 ± 0.11^{b}	NS
Remarks	*	*	

*Natural + CEPU: Natural pasture oversown with *Centrosema pubescence.*

Natural + STHA: Natural pasture oversown with *Stylosanthes hamata*

Natural + MAAT: Natural pasture oversown with *Macroptilium atropurpureum.*

Natural + CLTE: Natural pasture oversown with *Clitoria ternatea*

Natural: Natural pasture

NS= Non significant (P>0.05)

Means within the same column having different superscripts are significantly different (P<0.05).

4.5 Percentage composition of the oversown legumes

Percentage composition of the oversown legumes are shown in Figure 3. The legume species were seeded at the end of 1992 as pure stands. Then as years passed the plots became invaded with grasses (Chibuwana, 2000). Except for the year 1998, the treatments were not clipped or grazed by animals. The percentage composition (in weight) presented here was that done in the year 2000 i.e. after seven years of seeding. *Centrosema pubescence* did not survive the competition from the associated species and as a result it disappeared from the experimental field. The exact date of disappearance could not be identified, as there was no information available.

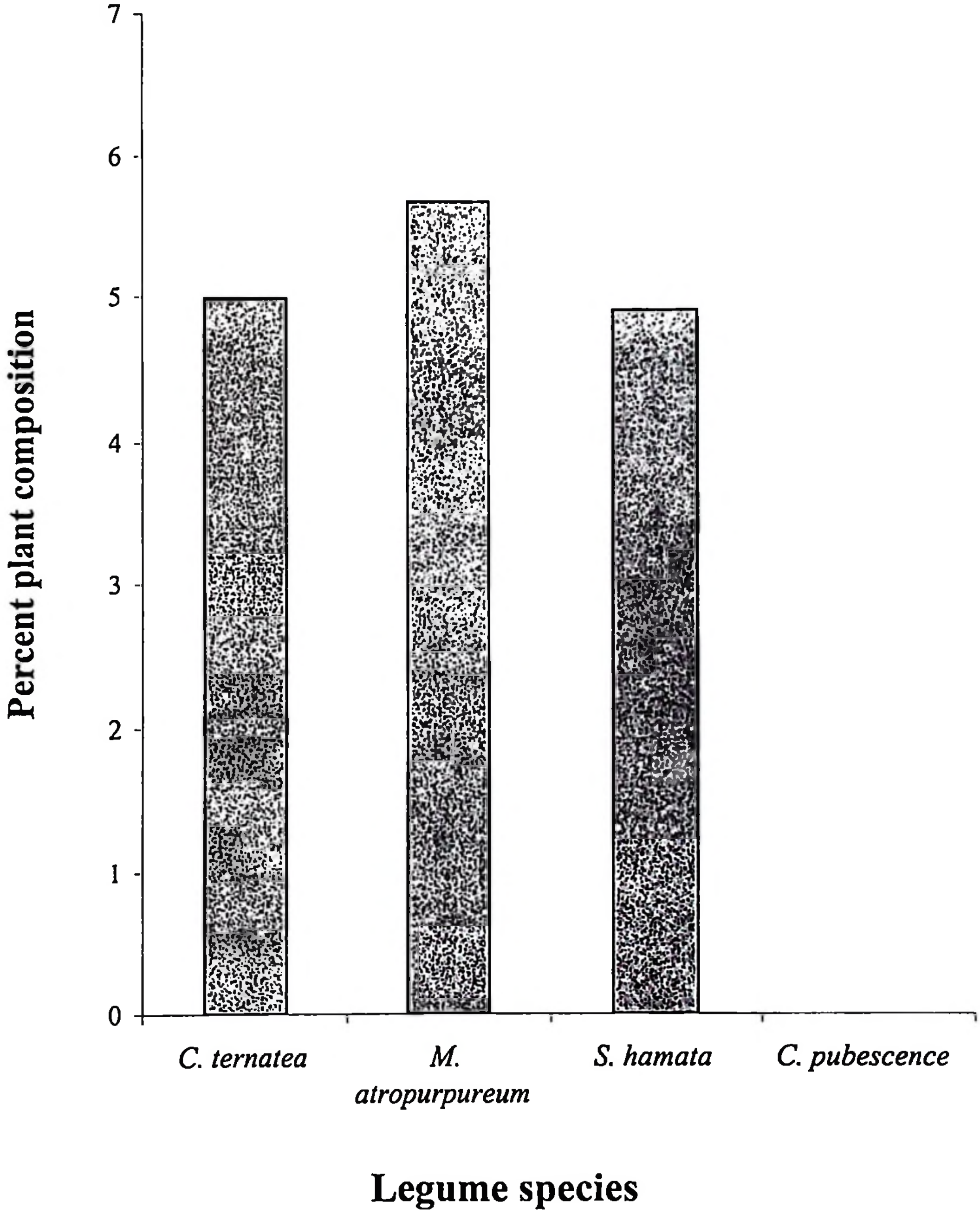

Figure 3: Percentage composition of the oversown legumes during the experimental period.

The percentage biomass composition of the legumes in the mixture was 5.68 percent for *Macroptilium atropurpureum*, 4.99 percent for *Clitoria ternatea* and 4.91 percent for *Stylosanthes hamata*. *Macroptilium atropurpureum* appeared to be more aggressive than the other legumes

4.6 Chemical composition of the treatments

4.6.1 Dry season

The chemical composition of forages from different treatments during the dry season is presented in Table 6. The crude protein (CP) content of the treatments ranged from 29.7 g/kg DM for the control treatments to 44 g/kg DM for treatments oversown with *Clitoria ternatea.* Crude protein content of the *C. ternatea* oversown treatment was significantly higher ($P<0.05$) than the other treatments. The control treatment had the lowest CP and was significantly lower than the others ($P<0.05$) except the *Centrosema pubescence* oversown treatment which did not differ significantly ($P>0.05$).

The ether extract (EE) content of the treatments ranged from 6.5 g/kg DM for *C. pubescence* plot to 10.4 g/kg DM for *Macroptilium* oversown treatments. Samples from *Macroptilium atropurpureum* oversown treatments had significantly higher ($P<0.001$) EE content than the other treatments. The EE content of *C. pubescence* oversown treatment and the control were significantly lower ($P<0.001$). However, there was no significant difference ($P>0.05$) between the two.

High NDF content, which was 797.3 g/kg DM, was recorded for *C. pubescence* oversown treatment while the lowest, 768.7 g/kg DM was for *C. ternatea* oversown treatment. There was no significant difference (P>0.05) in NDF content of treatments oversown with *C. pubescence*, *S. hamata*, *M. atropurpureum* and the control treatments. However, *C. ternatea* oversown treatments were significantly lower (P<0.05) than the *C. pubescence* oversown treatments while they were not significantly different (P>0.05) from the others. There was significant difference in Acid Detergent Fiber (ADF) content of the treatments. Samples from *C. pubescence* and *S. hamata* oversown treatments had significantly higher (P<0.05) ADF content than the other treatments. There was no significant difference (P>0.05) in ADF content between *C. pubescence*, *S. hamata* and *M. atropurpureum* over-sown treatments. *M. atropurpureum* and *C. ternatea* oversown and the control treatments did not significantly differ (P>0.05) in ADF content. Acid Detergent Lignin (ADL) content was not significantly (P>0.05) different among treatments. Ash content of *C. pubescence* oversown treatment was significantly higher (P<0.05) and that of *S. hamata* oversown treatment was significantly lower (P<0.05).

Table 6: Chemical composition of different treatment groups during the dry season at ICRAF-Lubaga Research site, in Shinyanga

Treatments	Parameters (g/kg DM)					
	CP	EE	NDF	ADF	ADL	Ash
Natural + CEPU	35.0 ± 1.9^{bc}	6.5 ± 0.2^{c}	797.3 ± 8.1^{a}	522.2 ± 4.4^{a}	489.4 ± 5.8^{a}	124.2 ± 0.8^{a}
Natural + STHA	37.6 ± 1.9^{b}	8.2 ± 0.2^{b}	783.3 ± 8.1^{ab}	520.8 ± 4.4^{a}	488.8 ± 5.8^{a}	106.2 ± 0.8^{c}
Natural + MAAT	36.5 ± 1.9^{b}	10.4 ± 0.2^{a}	778.8 ± 8.1^{ab}	511.9 ± 4.4^{ab}	491.8 ± 5.8^{a}	101.8 ± 0.8^{d}
Natural + CLTE	44.4 ± 1.9^{a}	8.3 ± 0.2^{b}	768.7 ± 8.1^{b}	500.1 ± 4.4^{b}	476.2 ± 5.8^{a}	102.7 ± 0.8^{d}
Natural pasture	29.7 ± 1.9^{c}	6.7 ± 0.2^{c}	788.3 ± 8.1^{ab}	507.5 ± 4.4^{b}	491.8 ± 5.8^{a}	112.6 ± 0.8^{b}

Means within the same column having different superscripts are significantly different (P<0.05).

It was evident that protein content of the pasture had increased with the oversown treatments showing the role of the legume in improving the dry season feed quality.

4.6.2 Wet season

4.6.2.1 Chemical composition of the wet season natural pasture and the mixed samples

Table 7 shows the chemical composition of the natural and mixed forage samples from different treatments. The CP content of the natural pasture ranged between 43 g/kg DM for the control treatment to 55.4 g/kg DM for *S. hamata* oversown treatment. Natural pasture from treatments oversown with *S. hamata* and *C. ternatea* had significantly higher ($P<0.05$) CP content than the rest of the treatments. The control treatment had significantly lower ($P<0.001$) CP content than the natural pasture of the oversown treatments. Natural pasture from *S. hamata* and *M. atropurpureum* oversown treatments had significantly higher ($P<0.05$) EE content than the other treatments. Significantly lower ($P<0.05$) EE was found for natural pasture from *C. ternatea* oversown treatment. The NDF and ADF content of natural pasture of the control and *C. pubescence* oversown treatments were significantly higher ($P<0.001$) than the rest. There was no significant difference ($P>0.05$) in NDF content between natural pasture samples from treatments oversown with *S. hamata*, *M. atropurpureum* and *C. ternatea*. Natural pasture samples from treatments oversown with *S. hamata, C. ternatea* and the control treatments had significantly higher ($P<0.05$) ADL content than the other treatments and there was no significant difference ($P>0.05$) among them. The ash content of the natural pasture samples from treatments oversown with *C. pubescence* and *M. atropurpureum* were significantly higher (P<0.05), however, there was no significant difference (P>0.05) between treatments.

The CP content of the mixed samples from treatments oversown with *S. hamata*, *M. atropurpureum* and *C. ternatea* were significantly higher (P<0.001) than the CP of the natural pasture from the same treatments. There was no significant difference (P>0.05) between the natural pasture and the mixed samples in EE, NDF, ADL, and ash content for the treatments oversown with *S. hamata*. Except for the NDF content of the natural pasture, which was significantly higher (P<0.05) than the mixed samples, there was no significant difference (P>0.05) in EE, ADF, ADL, and ash content between the natural pasture and mixed samples from treatments oversown with *M. atropurpureum*. The EE and NDF content of the mixed samples from *C. ternatea* oversown treatments were significantly higher (P<0.05) than the EE and NDF content of the natural pasture from the same treatment. The ADF content of the natural pasture from *C. ternatea* oversown treatments were significantly higher (P<0.05) than the mixed samples from the same treatments. There was no significant difference (P>0.05) in ADL and ash content between the natural pasture and the mixed samples from *C. ternatea* oversown treatments.

The crude protein content of the mixed samples from *C. ternatea* and *S. hamata* oversown treatments were significantly higher (P<0.05) than the mixed samples of the other treatments. Samples from *C. pubescence* oversown and the control treatments had significantly lower (P<0.05) CP content than the mixed samples of the oversown treatments. The EE content of the mixed samples from *S. hamata* oversown treatments were significantly higher (P<0.05) than the other treatments while the mixed samples from *C. ternatea* oversown samples had significantly lower (P<0.05) EE content. Mixed samples from *S. hamata* and *M. atropurpureum* oversown treatments had significantly lower NDF (P<0.05) content than *C. ternatea* mixed samples. The ADL content of the control treatment was significantly higher (P<0.05) while there was no significant difference (P>0.05) among the treatments oversown with *C. pubescence, S. hamata, M. atropurpureum* and *C. ternatea*. There was no significant difference (P>0.05) in ash content among the different treatments.

These results show that the protein content of the natural pasture mixed with the legumes were higher than the natural pasture alone. Legumes did not have any influence on the other nutrient components. The natural pasture from treatments oversown with *C. ternatea* and *S. hamata* had higher protein content. Ether extract content of the natural pasture associated with *S. hamata* and *M. atropurpureum* was higher than the EE from the other treatments.

Table 7: Mean chemical composition for the natural and the mixed pasture samples during the wet season at ICRAF-Lubaga Research site in Shinyanga region.

Treatment	Parameter	Pasture type (g/kg DM)		Remarks
		Natural	Mixture	
Natural + CEPU[1]	CP	49.0 ± 1.2^{b}	49.0 ± 1.2^{c}	NS
	EE	19.9 ± 0.4^{b}	19.9 ± 0.4^{c}	NS
	NDF	702.2 ± 5.1^{a}	702.2 ± 5.1^{a}	NS
	ADF	412.2 ± 4.9^{a}	412.2 ± 4.9^{a}	NS
	ADL	49.5 ± 4.1^{b}	49.5 ± 4.1^{b}	NS
	Ash	112.9 ± 4.6^{a}	112.9 ± 4.6^{a}	NS
Natural + STHA	CP	55.4 ± 1.2^{a}	59.7 ± 1.2^{b}	***
	EE	22.3 ± 0.4^{a}	22.7 ± 0.4^{a}	NS
	NDF	667.3 ± 5.1^{b}	664.2 ± 5.1^{c}	NS
	ADF	396.1 ± 4.9^{b}	396.8 ± 4.9^{b}	NS
	ADL	55.1 ± 4.1^{a}	50.1 ± 4.1^{b}	NS
	Ash	105.3 ± 4.6^{b}	101.4 ± 4.6^{a}	NS
Natural + MAAT	CP	49.1 ± 1.2^{b}	65.6 ± 1.2^{a}	***
	EE	21.3 ± 0.4^{a}	21.2 ± 0.4^{b}	NS
	NDF	674.8 ± 5.1^{b}	658.8 ± 5.1^{c}	*
	ADF	386.7 ± 4.9^{b}	384.4 ± 4.9^{bc}	NS
	ADL	46.9 ± 4.1^{b}	45.1 ± 4.1^{b}	NS
	Ash	119.8 ± 4.6^{a}	110.0 ± 4.6^{a}	NS
Natural + CLTE	CP	55.3 ± 1.2^{a}	68.8 ± 1.2^{a}	***
	EE	15.5 ± 0.4^{c}	19.9 ± 0.4^{c}	***
	NDF	665.4 ± 5.1^{b}	681.2 ± 5.1^{b}	*
	ADF	391.3 ± 4.9^{b}	373.4 ± 4.9^{c}	*
	ADL	61.9 ± 4.1^{a}	60.1 ± 4.1^{b}	NS
	Ash	106.3 ± 4.6^{b}	105.7 ± 4.6^{a}	NS
Natural[1]	CP	43.0 ± 1.2^{c}	$4.3.0\pm1.2^{c}$	NS
	EE	12.1 ± 0.4^{d}	12.1 ± 0.4^{d}	NS
	NDF	703.5 ± 5.1^{a}	703.5 ± 5.1^{a}	NS
	ADF	422.4 ± 4.9^{a}	422.4 ± 4.9^{a}	NS
	ADL	66.4 ± 4.1^{a}	66.4 ± 4.1^{a}	NS
	Ash	106.6 ± 4.6^{b}	106.6 ± 4.6^{a}	NS

NS - Non significant (P>0.05)

* - Significant (P<0.05)

*** - Significant (P<0.001)

[1] The same value was used twice for comparing within type hence not used to compare between types.

Means within the same column for the same parameter having different superscripts are significantly different (P<0.05).

It is therefore evident that the protein content of the mixed samples from *C. ternatea* and *M. atropurpureum* oversown treatments were higher than the mixed pasture of the other treatments. *S. hamata* oversown pasture showed higher ether extract content than the others. The cell wall content (NDF) of the mixed pasture from *S. hamata* and *M. atropurpureum* were higher than the treatments oversown with *C. ternatea*, *C. pubescence* and the control.

4.6.2.2 Chemical composition of the natural pasture and the oversown legumes

Table 8 presents the chemical composition of the oversown legumes alone and the natural pasture. The crude protein content of the oversown leguminous forage species; *Stylosanthes hamata, Clitoria ternatea* and *Macroptilium atropurpureum* was significantly higher ($P<0.001$) compared to the natural pasture. *Clitoria ternatea* and *M. atropurpureum* were significantly higher ($P<0.001$) in EE content while *S. hamata* was lower ($P<0.01$) than the natural pasture. The natural pasture had significantly higher ($P<0.001$) NDF and ADF content than the oversown legumes. The oversown legumes had significantly higher ($P<0.05$) ADL content than the natural pasture. The ash content of *S. hamata* was significantly higher ($P<0.001$) while that of *M. atropurpureum* and *C. ternatea* was significantly lower ($P<0.01$).

Table 8: Mean chemical composition for the natural pasture and the oversown legume species during the wet season at ICRAF-Lubaga Research site, in Shinyanga region.

Treatment	Parameter	Pasture type (g/kg DM)		Remarks
		Natural	Legume	
Natural + STHA	CP	55.4 ± 1.8^{a}	104.4 ± 1.8^{c}	***
	EE	22.3 ± 0.6^{a}	18 ± 0.6^{c}	***
	NDF	667.3 ± 4.3^{b}	543.1 ± 4.3^{a}	***
	ADF	396.1 ± 4.4^{b}	376.1 ± 4.4^{a}	**
	ADL	55.1 ± 4.8^{a}	75.1 ± 4.8^{a}	**
	Ash	105.3 ± 2.0^{b}	122.3 ± 2.0^{a}	***
Natural + MAAT	CP	49.1 ± 1.8^{b}	142.1 ± 1.8^{b}	***
	EE	21.3 ± 0.6^{a}	30.7 ± 0.6^{b}	***
	NDF	674.8 ± 4.3^{b}	521.4 ± 4.3^{b}	***
	ADF	386.7 ± 4.4^{b}	365.7 ± 4.4^{a}	**
	ADL	46.9 ± 4.8^{b}	81.7 ± 4.8^{a}	***
	Ash	119.8 ± 2.0^{a}	75 ± 2.0^{c}	***
Natural + CLTE	CP	55.3 ± 1.8^{a}	151.9 ± 1.8^{a}	***
	EE	15.5 ± 0.6^{c}	33 ± 0.6^{a}	***
	NDF	665.4 ± 4.3^{b}	486.4 ± 4.3^{c}	***
	ADF	391.3 ± 4.4^{b}	323.4 ± 4.4^{b}	***
	ADL	61.9 ± 4.8^{a}	88.9 ± 4.8^{a}	***
	Ash	106.3 ± 2.0^{b}	87.8 ± 2.0^{b}	***
Natural + CEPU[1]	-	-	-	-

[1]Was not sampled

* - Significant (P<0.05)

** - Significant (P<0.01)

*** - Significant (P<0.001)

Means within the same column for the same parameter having different superscript are significantly different (P<0.05).

The CP contents of the oversown legumes in g/kg DM were 104.4 for *S. hamata*, 142.1 for *M. atropurpureum* and 151.9 for *C. ternatea*. *C. ternatea* had significantly higher ($P<0.001$) CP content than *S. hamata* and *M. atropurpureum* while *S. hamata* had significantly lower ($P<0.001$) CP content. *C. ternatea* had significantly higher ($P<0.001$) EE content than *S. hamata* and *M. atropurpureum*. Significantly lower ($P<0.05$) EE content was found from *S. hamata*. *S. hamata* had significantly higher NDF ($P<0.05$) while *C. ternatea* had the lowest. The ADF content of *S. hamata* and *M. atropurpureum* was significantly higher ($P<0.001$) than that of *C. ternatea*. There was no significant difference ($P>0.05$) in the ADL content between the oversown legume species. The ash content of *S. hamata* was significantly higher ($P<0.001$) while that of *C. ternatea* was significantly lower ($P<0.05$) than that of *M. atropurpureum*.

From these results, the oversown legumes were higher in crude protein content than the natural pasture. It is therefore evident that inclusion of legumes in the natural pasture can contribute to the increase in the CP content of the pasture.

4.6.3 Chemical composition during the dry and wet seasons

Comparison of dry season samples with wet season mixed samples is presented in Table 9. The CP and EE content of the wet season mixed samples were significantly higher ($P<0.001$) than the dry season samples. The wet season mixed samples had significantly lower ($P<0.001$) NDF, ADF and ADL content than the dry season samples. There was no significant difference ($P>0.05$) in ash content between the dry season and the wet season samples.

Table 9: Comparison of the chemical composition for the different mixed pasture (grass and legumes) during the wet and dry seasons at ICRAF-Lubaga Research site in Shinyanga Region.

Treatment	Parameter	Pasture type (g/kg DM)		Remarks
		Dry season (Mixed)	Wet season (Mixed)	
Natural + CEPU	CP	35.0 ± 1.8bc	49.0 ± 1.8^{c}	***
	EE	6.5± 0.8c	19.9 ± 0.8^{c}	***
	NDF	797.3 ± 8.5a	702.2 ± 8.5^{a}	***
	ADF	522 2± 7.6a	412.2 ± 7.6^{a}	***
	ADL	489.4 ± 5.0a	49.5 ± 4.1^{b}	***
	Ash	124.2± 4.4a	112.5 ± 4.4^{a}	NS
Natural + STHA	CP	37.6 ± 1.8^{b}	59.7 ± 1.8^{b}	***
	EE	8.2 ± 0.8^{b}	22.7 ± 0.8^{a}	***
	NDF	783.3 ± 8.5^{ab}	664.2 ± 8.5^{c}	***
	ADF	520.8 ± 7.6^{a}	396.8 ± 7.6^{b}	***
	ADL	488.8 ± 5^{a}	50.1 ± 4.1^{b}	***
	Ash	106.2 ± 4.4^{c}	113.9 ± 4.4^{a}	NS
Natural + MAAT	CP	36.5 ± 1.8^{b}	65.6 ± 1.8^{a}	***
	EE	10.4 ± 0.8^{a}	21.2 ± 0.8^{b}	***
	NDF	778.8 ± 8.5^{ab}	658.8 ± 8.5^{c}	***
	ADF	511.9 ± 7.6^{ab}	384.4 ± 7.6^{bc}	***
	ADL	491.8 ± 5.0^{a}	45.1 ± 4.1^{b}	***
	Ash	101.8 ± 4.4^{d}	110.0 ± 4.4^{a}	NS
Natural + CLTE	CP	44.4 ± 1.8^{a}	68.8 ± 1.8^{a}	***
	EE	8.3 ± 0.8^{b}	19.9 ± 0.8^{c}	***
	NDF	768.7 ± 8.5^{b}	681.2 ± 8.5^{b}	***
	ADF	500.1 ± 7.6^{b}	373.4 ± 7.6^{c}	***
	ADL	476.2 ± 5^{a}	50.1 ± 4.1^{b}	***
	Ash	102.7 ± 4.4^{d}	105.7 ± 4.4^{a}	NS
Natural	CP	29.7 ± 1.8^{c}	43.0 ± 1.8^{c}	***
	EE	6.7 ± 0.8^{c}	12.1 ± 0.8^{d}	***
	NDF	788.3 ± 8.5^{ab}	703.5 ± 8.5^{a}	***
	ADF	507.5 ± 7.6^{b}	422.4 ± 7.6^{a}	***
	ADL	491.8 ± 5^{a}	66.4 ± 4.1^{a}	***
	Ash	112.6 ± 4.4^{b}	106.6 ± 4.4^{a}	NS

NS – Non significant ($P>0.05$)

*** - Significant ($P<0.001$)

Means within the same column for the same parameters having different superscripts are significantly different ($P<0.05$)

As it would be expected, the wet season forage was higher in nutritional quality than the dry season pasture.

4.7 Digestibility

4.7.1 Dry season

In vitro dry matter (IVDM) and organic matter (IVOM) digestibility for the dry season samples are shown in Table 10. The *in vitro* dry matter digestibility ranged between 231.5 g/kg DM for the control treatment to 383.4 g/kg DM for *C. ternatea* oversown treatment. The IVOM digestibility ranged between 304 g/kg DM for the control treatment to 425.2 g/kg DM for *C. ternatea* oversown treatments. The control and *C. pubescence* oversown treatments had significantly lower (P<0.05) dry matter and organic matter digestibility than the other treatments. The DM digestibility of *C. ternatea* and *S hamata* oversown treatments were significantly higher (P<0.05). *C. ternatea*, oversown treatment showed significantly higher (P<0.05) OM digestibility than the other treatments.

Table 10: Mean *In vitro* dry matter and organic matter digestibility for the different oversown treatments during the dry season at ICRAF-Lubaga Research site in Shinyanga Region.

Treatments	Digestibility (g/kg DM)	
	DM	OM
Natural + CEPU	246.3±4.0^{d}	318.5±8.7^{c}
Natural + STHA	366.8±4.0^{a}	375.7±8.7^{b}
Natural + MAAT	321.0±4.0^{c}	351.8±8.7^{b}
Natural + CLTE	383.4±4.0^{a}	425.2±8.7^{a}
Natural	231.5±4.0^{d}	304.0±8.7^{c}

Means within the same column having similar superscripts are not significantly different (P>0.05).

Legume oversown treatments, except for *C. pubescence*, were higher in their dry matter and organic matter digestibility than the natural pasture. This was associated with the relatively higher CP content of the oversown treatments.

4.7.2 Wet season

4.7.2.1 Dry matter and organic matter digestibility of the wet season natural pasture and mixed samples.

In vitro dry matter and organic matter digestibility of the wet season natural pasture and the mixed samples are shown in Table 11. The *in vitro* dry matter digestibility of the natural pasture ranged from 419.9 g/kg DM for the control treatment to 435.7 g/kg DM for the natural pasture from *C. ternatea* oversown treatment. Organic matter digestibility of the natural pasture varied from 456 g/kg DM for *C. pubescence* oversown treatments to 477 g/kg DM for *M. atropurpureum* oversown treatments. The natural pasture from different treatments did not significantly differ (P>0.05) in OM and DM digestibility.

Dry matter digestibility for the mixed samples varied from 419.9 g/kg DM to 478.3 g/kg DM for the control and *C. ternatea* oversown treatments respectively. The OM digestibility ranged from 456 g/kg DM to 506.6 g/kg DM for *C. pubescence* and *M. atropurpureum* oversown treatments respectively. The OM and DM digestibility of the mixed samples from treatments oversown with *S. hamata*, *M. atropurpureum* and *C. ternatea* were higher than the control.

Mixed samples from *M. atropurpureum* and *C. ternatea* oversown treatments were significantly higher (P<0.05) in *in vitro* DM digestibility than the natural pasture from the same treatment. There was no significant difference (P>0.05) in *in vitro* DM digestibility between the natural pasture and the mixed samples from *S. hamata* oversown treatment. There was no significant difference (P>0.05) in *in vitro* OM digestibility between the natural pasture and the mixed samples from *S. hamata, M. atropurpureum* and *C. ternatea* oversown treatments.

Mixed samples from treatments oversown with *S. hamata*, *M. atropurpureum* and *C. ternatea* were significantly higher (P<0.05) in IVDM and IVOM digestibility than the treatments oversown with *C. pubescence* and the control.

Table 11: Mean *in vitro* dry matter and organic matter digestibility for the natural pasture and the mixtures (grass and legume) during the wet season at ICRAF-Lubaga Research site in Shinyanga Region.

Treatment		Digestibility (g/kg DM)		Remarks
		Natural pasture	Mixed pasture	
Natural + CEPU	DM	426.8 ± 10.3^a	426.8 ± 10.3^b	NS
	OM	456.0 ± 13.8^a	456.0 ± 13.8^a	NS
Natural + STHA	DM	434.3 ± 10.3^a	447.3 ± 10.3^a	NS
	OM	470.3 ± 13.8^a	485.9 ± 13.8^a	NS
Natural + MAAT	DM	427.3 ± 10.3^a	478.2 ± 10.3^a	**
	OM	477.0 ± 13.8^a	506.6 ± 13.8^a	NS
Natural + CLTE	DM	435.7 ± 10.3^a	478.3 ± 10.3^a	*
	OM	470.6 ± 13.8^a	493.9 ± 13.8^a	NS
Natural pasture	DM	419.9 ± 10.3^a	419.9 ± 10.3^b	NS
	OM	457.4 ± 13.8^a	457.4 ± 13.8^b	NS

NS - Non significant ($P>0.05$)

* - Significant ($P< 0.05$)

** - Significant ($P<0.01$)

Means within the same column for the same parameter having different superscripts are significantly different ($P<0.05$).

From these results, the oversown legumes had significantly improved the OM and DM digestibility during the wet season. Treatments oversown with *M. atropurpureum* and *C. ternatea* (mixed pasture) showed higher *in vitro* dry matter digestibility than the natural pasture

4.7.2.2 Dry matter and organic matter digestibility of the wet season natural pasture and the oversown legume species

Dry matter and organic matter digestibility of the wet season natural pasture and the oversown legume species are shown in Table 12. The oversown legumes were significantly higher (P<0.05) in IVDM and IVOM matter digestibility than the natural pasture. *S. hamata* showed significantly higher (P<0.05) IVDM and IVOM digestibility than *M. atropurpureum* and *C. ternatea*.

Table 12: Mean *in vitro* dry matter and organic matter digestibility for the natural pasture and the oversown legumes during the wet season at ICRAF-Lubaga Research site in Shinyanga Region

Treatment		Digestibility (g/kg DM)		Remarks
		Natural pasture	Legumes Spp.	
Natural +STHA	DM	434.3±10.3^a	534.0±10.3^a	**
	OM	470.3±13.8^a	572.2±13.8^a	**
Natural + MAAT	DM	427.3±10.3^a	484.1±10.3^b	*
	OM	477.0±13.8^a	511.5±13.8^b	*
Natural + CLTE	DM	435.7±10.3^a	460.4±10.3^b	***
	OM	470.6±13.8^a	547.8±13.8^b	***
Natural + CEPU[1]		-	-	-

[1] Was not sampled.

* - Significant (P<0.05)

** - Significant (P<0.01)

*** - Significant (P<0.001)

Means within the same column for the same parameter having different superscripts are significantly different (P<0.05).

As is shown in Table 12, the legumes had higher IVDM and OM digestibility than the natural pasture. *C. ternatea* had higher IVDM digestibility whereas *S. hamata* had higher IVOM digestibility.

4.7.3 Comparison of *in vitro* DM and OM digestibility during the wet and dry seasons

In vitro dry matter and organic matter digestibility of the dry and wet season samples are shown in Table 13. The wet season samples were significantly higher ($P<0.001$) in both IVDMD and IVOMD than the dry season samples. This was associated with the low cell wall and relatively higher CP content of the wet season samples. As one could expect in both seasons for all types of samples the OM digestibility was higher than the DM digestibility.

Table 13: Comparison of *In vitro* dry matter and organic matter digestibility for the dry season samples and wet season of mixed samples at ICRAF-Lubaga research site, in Shinyanga Region.

Treatment		Digestibility (g/kg DM)		Remarks
		Natural (Dry season)	Mixed (Wet season)	
Natural + CEPU	DM	246.3 ± 4.0^{d}	426.8 ± 10.3^{b}	***
	OM	318.5 ± 8.7^{c}	456.0 ± 13.8^{a}	***
Natural + STHA	DM	366.8 ± 4.0^{a}	434.3 ± 10.3^{a}	***
	OM	375.7 ± 8.7^{b}	470.3 ± 13.8^{a}	***
Natural + MAAP	DM	321.0 ± 4.0^{c}	427.3 ± 10.3^{a}	***
	OM	351.8 ± 8.7^{b}	477.0 ± 13.8^{a}	***
Natural + CLTE	DM	383.4 ± 4.0^{a}	435.7 ± 10.3^{a}	***
	OM	425.2 ± 8.7^{a}	470.6 ± 13.8^{a}	***
Natural pasture	DM	231.5 ± 4.0^{d}	419.9 ± 10.3^{b}	***
	OM	304.0 ± 8.7^{c}	457.4 ± 13.8^{b}	***

*** - Significant ($P<0.001$)

Means within the same column for the same parameter having different superscripts are significantly different ($P<0.05$).

4.8 Degradability and degradation characteristics.

4.8.1 Dry season

The dry season 48 hrs forage degradability and degradation characteristics are indicated in Table 14. There was no significant difference (P<0.05) between different treatments in 48 hr degradability and rate constants. The water soluble or immediate available fraction and potential degradability of all treatments were significantly higher (P<0.05) than the control. There was significant difference (P<0.05) in rate of degradation among different treatments.

Table 14: Mean *in Sacco* 48 hrs degradability and degradation characteristics for forage samples oversown with legumes during the dry season at ICRAF-Lubaga Research site in Shinyanga Region.

Treatments	Parameters (g/kg DM)			
	Degradability 48 hrs	*a*	*a+b*	*c*
Natural + CEPU	508.4±9.9^{a}	157.6±11.2^{a}	572.9±9.2^{a}	0.39±0.1^{a}
Natural + STHA	502.6±9.9^{a}	176.0±11.2^{a}	577.7±9.2^{a}	0.42±0.1^{a}
Natural + MAAT	523.9±9.9^{a}	160.9±11.2^{a}	585.1±9.2^{a}	0.30±0.1^{a}
Natural + CLTE	525.2±9.9^{a}	170.0±11.2^{a}	600.6±9.2^{a}	0.36±0.1^{a}
Natural pasture	506.0±9.9^{a}	75.5±11.2^{b}	492.0±9.2^{b}	0.39±0.1^{a}
Remarks	NS	*	*	NS

NS Non significant (P>0.05)

* Significant (P<0.05)

Means within the same column having similar superscripts are not significantly different (P>0.05).

The potential degradability and water-soluble fractions were higher for treatments oversown with legumes. However the treatments did not significantly differ in other parameters among themselves.

Degradability curves for the dry season samples at different incubation periods are shown in Figure 4. For all treatments the DM disappearance had increased with increasing incubation time. The treatments achieved the asymptote of DM degradability at 96 hrs of incubation.

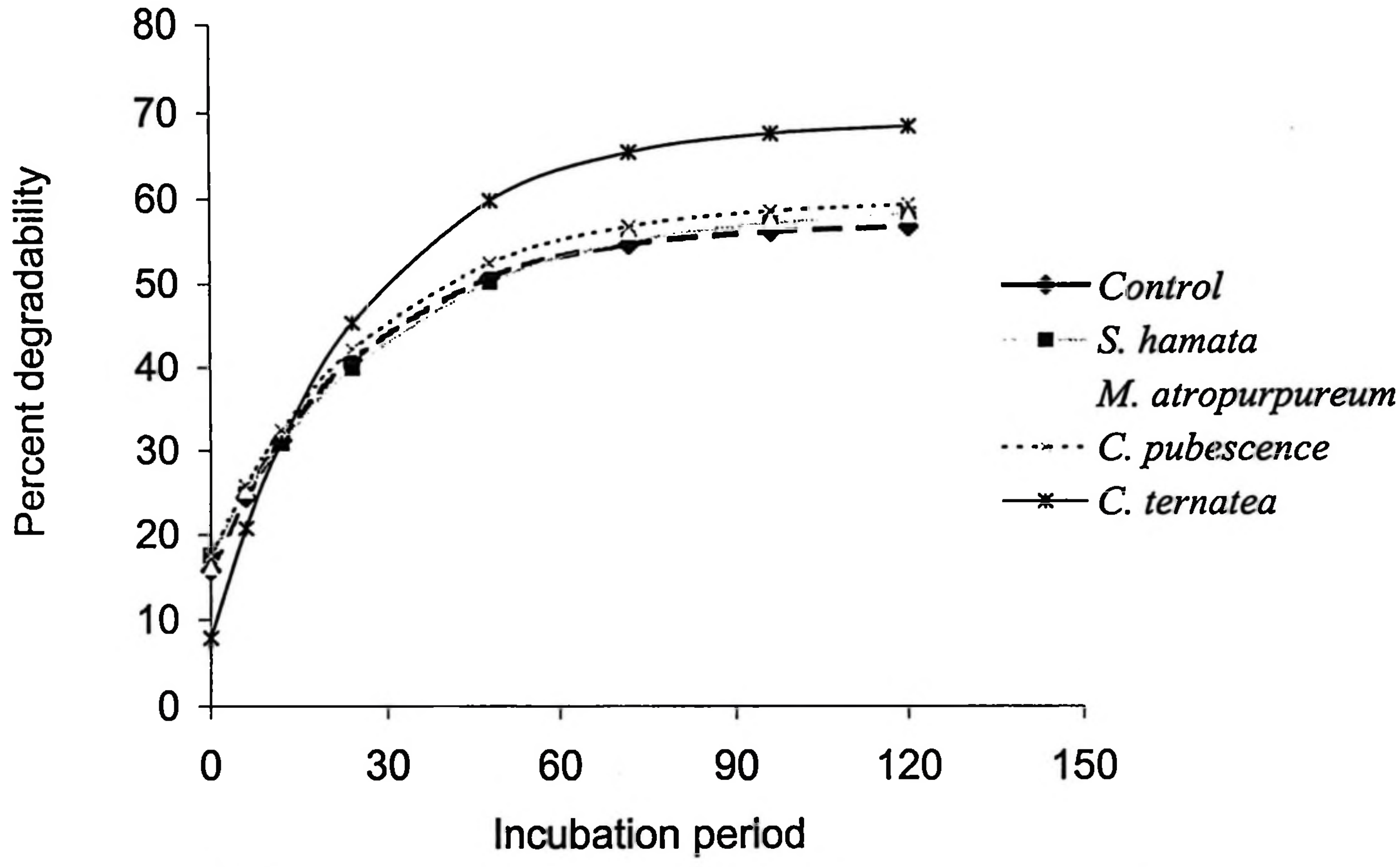

Figure 4: In sacco DM degradability of the dry season forage

4.8.2 Wet season degradability and degradation characteristics

4.8.2.1 Degradability and degradation characteristics of the natural pasture and the mixed samples

Table 15 shows the wet season 48 hrs degradability, water-soluble fraction, potential degradability and degradation rate results for the natural pasture and the mixed samples. There was no significant difference (P>0.05) in 48hrs degradability between the natural pasture and the mixed samples of different treatments. The water-soluble fraction and potential degradability of the mixed samples from *C. ternatea* oversown treatment were significantly higher (P<0.05) than the natural pasture from the same treatment. The water-soluble fraction, 48 hrs degradability, potential degradability and degradation rate of the natural and mixed samples from treatments oversown with *S. hamata* and *M. atropurpureum* did not significantly differ (P>0.05).

The natural pasture from treatments oversown with *S. hamata* was significantly higher (P<0.05) in 48 hrs degradability than the natural pasture from the other treatments. The control treatment had significantly lower (P<0.05) 48 hrs degradability than the other natural pasture samples. There was no significant difference (P>0.05) in degradation rate and water-soluble fractions between the natural pasture of the different treatments. Except for the natural pasture from *C. ternatea* oversown treatment, which was significantly lower (P<0.05) than the other, there was no significant difference (P>0.05) in potential degradability of natural pasture from different treatments.

Table 15: Mean *in sacco* 48 hours degradability and degradability constants for wet season natural and mixed (grass and legume) samples at ICRAF-Lubaga research site in Shinyanga Region.

Treatment	Parameters	Pasture type (g/kg DM)		Remarks
		Natural	Mixed	
Natural + CEPU[1]	Degrad (48 hrs)	669.6 ± 12.2^{b}	669.6 ± 12.2^{b}	NS
	a	202.9 ± 10.0^{a}	202.9 ± 10.0^{b}	NS
	a + b	741.0 ± 10.0^{a}	741.0 ± 10.0^{a}	NS
	c	0.42 ± 0.1^{a}	0.42 ± 0.1^{a}	NS
Natural + STHA	Degrad (48 hrs)	710.7 ± 12.2^{a}	747.7 ± 12.2^{a}	NS
	a	217.9 ± 10.0^{a}	223.8 ± 10.0^{a}	NS
	a + b	750.3 ± 10.0^{a}	752.9 ± 10.0^{a}	NS
	c	0.52 ± 0.1^{a}	0.45 ± 0.1^{a}	NS
Natural + MAAT	Degrad (48 hrs)	698.0 ± 12.2^{b}	713.2 ± 12.2^{a}	NS
	a	212.4 ± 10.0^{a}	240.5 ± 10.0^{a}	NS
	a + b	750.3 ± 10.0^{a}	752.9 ± 10.0^{a}	NS
	c	0.49 ± 0.1^{a}	0.39 ± 0.1^{a}	NS
Natural + CLTE	Degrad (48 hrs)	638.3 ± 12.2^{c}	646.4 ± 12.2^{b}	NS
	a	214.7 ± 10.0^{a}	246.2 ± 10.0^{a}	*
	a + b	682.5 ± 10.0^{b}	717.4 ± 10.0^{b}	*
	c	0.49 ± 0.1^{a}	0.39 ± 0.1^{a}	NS
Natural pasture[1]	Degrad (48 hrs)	670.3 ± 12.2^{b}	670.3 ± 12.2^{b}	NS
	a	204.7 ± 10.0^{a}	204.7 ± 10.0^{b}	NS
	a + b	713.8 ± 10.0^{a}	713.8 ± 10.0^{b}	NS
	c	0.51 ± 0.1^{a}	0.51 ± 0.1^{a}	NS

[1] The same values were used twice for comparing within type hence not used to compare between types.

NS – Non significant (P>0.05)

* – Significant (P<0.05)

Means within the same column for the same parameter having different superscripts are significantly different (P<0.05).

Mixed samples from treatments oversown with *S. hamata* and *M. atropurpureum* were significantly higher ($P<0.05$) in 48 hr degradability, water-soluble fraction and potential degradability than the other treatments. There was no significant difference ($P>0.05$) in degradation rate constant between mixed samples of different treatments.

Treatments oversown with *C. ternatea* had higher potential degradability than the natural pasture of the same treatment. The natural and mixed pasture from treatments oversown with legumes had higher potential degradability than the control treatment. There was no difference in degradation rate between different sample type of different treatments.

Dry matter degradability curves at different incubation periods for the wet season natural pasture are shown in Figure 5. The DM disappearance of the natural pasture for all treatments had increased with increasing incubation period. The asymptote of DM degradability for the different natural pasture samples was achieved at about 76 hour of incubation.

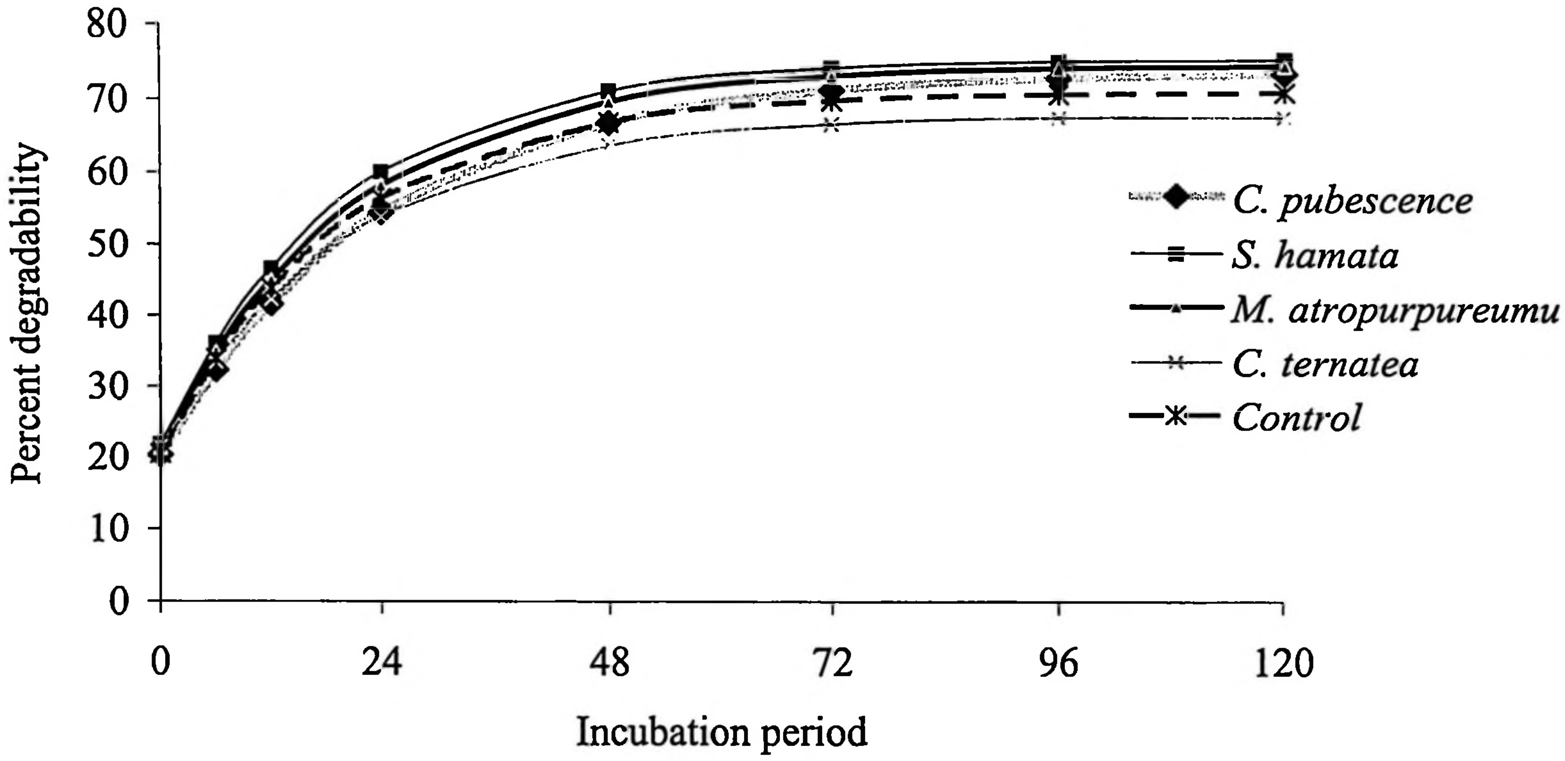

Figure 5: Dry matter degradability for the wet season natural grasses which were undersown with the different legume species

Dry matter degradability curves at different incubation periods for the mixed samples of the wet season are shown in Figure 6. The mixed samples were increasing in DM disappearance with increasing incubation period. Mixed samples from *S. hamata* and *M. atropurpureum* oversown treatments had similar trend in DM disappearance throughout the incubation period. The control treatment reached the asymptote of DM degradability between 48 and 72 hrs while samples from *C. pubescence* oversown treatments attained the asymptote of DM degradability at 96 hrs.

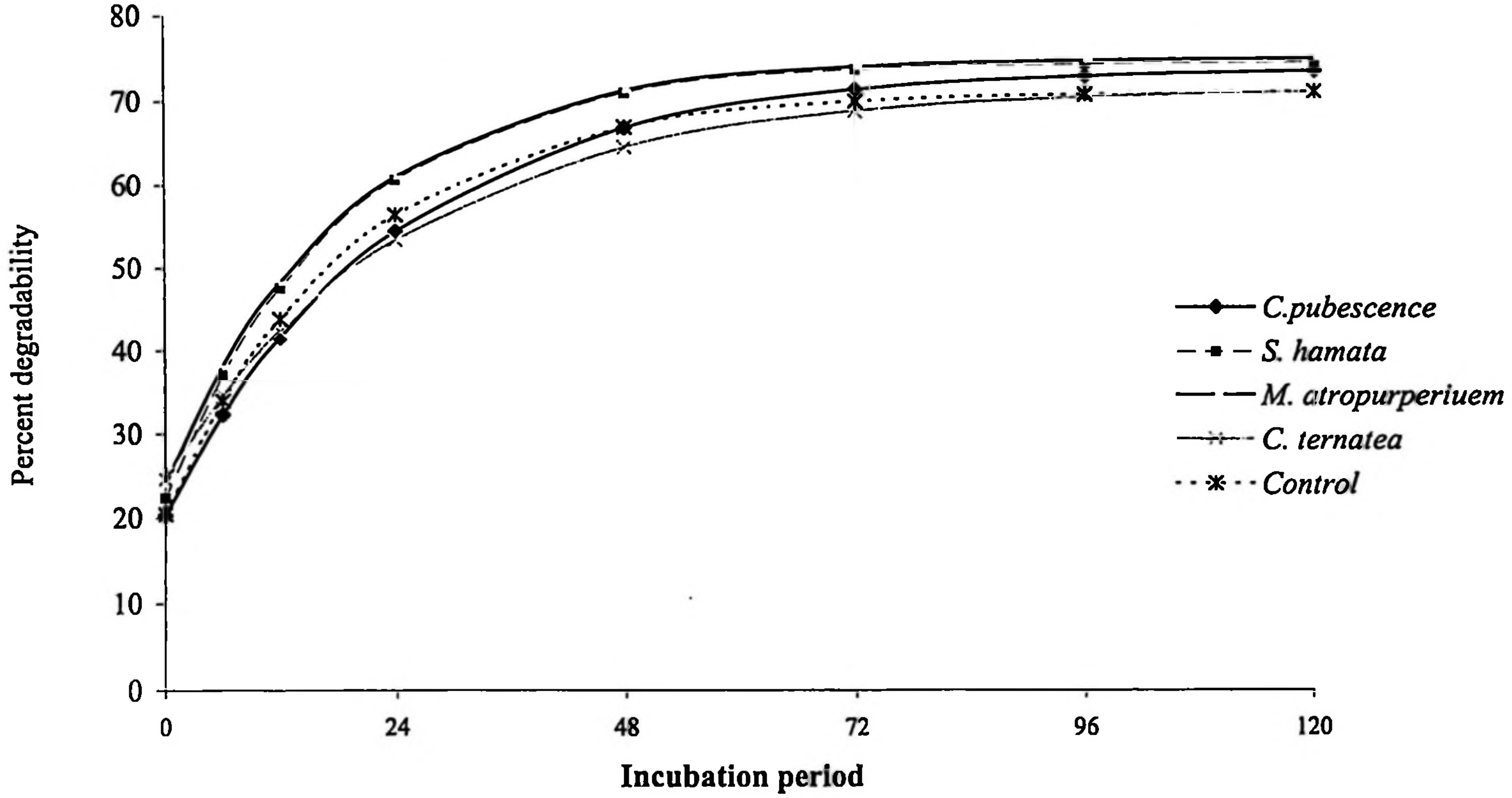

Figure 6: In sacco degradability of the wet season mixed samples

4.8.2.2 Degradability and degradation characteristics for the natural pasture and the oversown legume species

The wet season 48 hrs degradability, water-soluble fraction, potential degradability and rate constant results for the natural pasture and legumes are presented in Table 16.Except for 48 hrs degradability, *S. hamata* was significantly higher (P<0.05) in water-soluble fraction, potential degradability and degradation rate than the natural pasture. There was no significant difference (P>0.05) in water-soluble fraction, 48 hrs degradability, potential degradability and degradation rate values between *C. ternatea* and the natural pasture.

Table 16: Mean *in sacco* 48 hours degradability and degradability constants for the natural pasture and the different oversown legume species during the wet season at ICRAF-Lubaga Research site in Shinyanga Region

Treatment	Parameters	Degradability (g/kg DM)		Remarks
		Natural pasture	Legume spp.	
Natural + STHA	Degrad (48 hrs)	710.7 ± 12.2^{a}	747.7 ± 12.2^{a}	NS
	a	217.9 ± 10.0^{a}	308.1 ± 10.0^{a}	**
	a + *b*	750.3 ± 10.0^{a}	750.3 ± 10.0^{a}	*
	c	0.52 ± 0.1^{a}	0.95 ± 0.1^{a}	*
Natural + MAAT	Degrad (48 hrs)	698.0 ± 12.2^{b}	698.0 ± 12.2^{b}	NS
	a	212.4 ± 10.0^{a}	237.4 ± 10.0^{b}	NS
	a + *b*	750.3 ± 10.0^{a}	718.2 ± 10.0^{b}	NS
	c	0.49 ± 0.1^{a}	0.46 ± 0.1^{b}	NS
Natural + CLTE	Degrad (48 hrs)	638.3 ± 12.2^{c}	650.4 ± 12.2^{b}	NS
	a	214.6 ± 10.0^{a}	214.56 ± 10.0^{a}	NS
	a + *b*	682.5 ± 10.0^{b}	707.2 ± 10.0^{b}	NS
	c	0.49 ± 0.1^{a}	0.44 ± 0.1^{b}	NS
Natural + CEPU[1]	-	-	-	-

[1] was not sampled.

NS – Non significant (P>0.05)

** – Significant (P<0.01)

Means within the same column for the same parameter having different superscripts are significantly different (P<0.05).

S. hamata showed higher soluble fraction, potential degradability and rate constant than the natural pasture. *Stylosanthes hamata* was significantly higher (P<0.05) in 48hrs degradability, potential degradability and rate constant than *Clitoria ternatea* and *Macroptilium atropurpureum*.

Dry matter degradability curves at different incubation periods for the oversown legumes are shown in Figure 7. The oversown legumes had faster DM disappearance rate. The DM disappearance was increasing with increasing incubation period. *S. hamata* achieved its asymptote for DM disappearance faster than the other oversown legumes at 48^{th} hours.

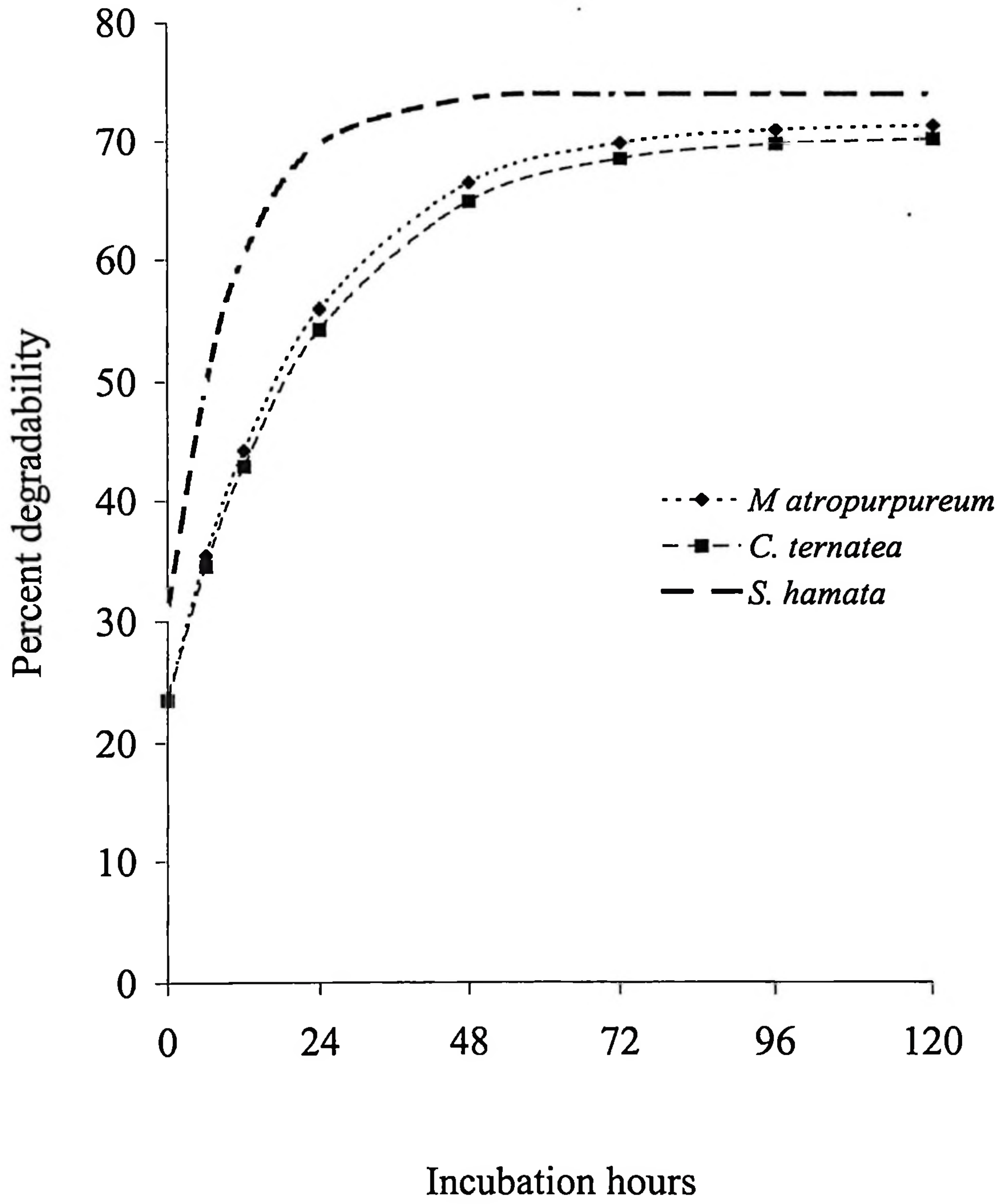

Figure 7: Dry matter degradability of legume samples.

4.8.3 Comparison of seasons for degradability and degradation characteristics

Table 17 presents *in sacco* dry matter degradability and degradation characteristics for the dry season samples and the wet season mixed samples. The 48 hrs degradability, water-soluble fraction and potential degradability of wet season mixed samples were significantly higher ($P<0.01$) than the dry season samples. There was no significant difference in degradation rate between the dry and wet season samples for all types of samples.

Table 17: Comparison of *in sacco* 48 hours degradability and degradability constant values for the dry and wet season mixed samples at ICRAF-Lubaga research site in Shinyanga Region

Treatment	Parameters	Degradability (g/kg DM)		Remarks
		Natural Pasture (Dry season)	Mixed pasture (wet season)	
Natural + CEPU	Degrad (48 hrs)	508.4 ± 9.9^{a}	669.6 ± 12.2^{b}	***
	a	157.6 ± 11.2^{a}	202.9 ± 10.0^{b}	**
	a + b	572.9 ± 9.2^{a}	741.0 ± 10.0^{a}	***
	c	0.39 ± 0.1^{a}	0.42 ± 0.1^{a}	NS
Natural + STHA	Degrad (48 hrs)	502.6 ± 9.9^{a}	710.7 ± 12.2^{a}	***
	a	176.0 ± 11.2^{a}	223.8 ± 10.0^{a}	**
	a + b	577.7 ± 9.2^{a}	752.9 ± 10.0^{a}	***
	c	0.42 ± 0.1^{a}	0.45 ± 0.1^{a}	NS
Natural + MAAT	Degrad (48 hrs)	523.9 ± 9.9^{a}	713.2 ± 12.2^{a}	***
	a	160.9 ± 11.2^{a}	240.5 ± 10.0^{a}	***
	a + b	585.1 ± 9.2^{a}	752.9 ± 10.0^{a}	***
	c	0.30 ± 0.1^{a}	0.39 ± 0.1^{a}	NS
Natural + CLTE	Degrad (48 hrs)	525.2 ± 9.9^{a}	646.4 ± 12.2^{b}	***
	a	170.0 ± 11.2^{a}	246.2 ± 10.0^{a}	***
	a + b	600.6 ± 9.2^{a}	717.4 ± 10.0^{b}	***
	c	0.36 ± 0.1^{a}	0.39 ± 0.1^{a}	NS
Natural pasture	Degrad (48 hrs)	506.0 ± 9.9^{a}	670.3 ± 12.2^{b}	***
	a	75.5 ± 11.2^{b}	204.7 ± 10.0^{b}	***
	a + b	492.0 ± 9.2^{b}	713.8 ± 10.0^{b}	***
	c	0.39 ± 0.1^{a}	0.51 ± 0.1^{a}	**

NS – Non significant ($P>0.05$)

** - Significant ($P<0.01$)

*** - Significant ($P<0.001$)

Means within the same column for the same parameter having the same superscript are not significantly different ($P>0.05$)

CHAPTER V

5.0 DISCUSSION

5.1 Soil physical and chemical properties

Oversowing legumes into the natural pasture increased the soil fertility status significantly. Nitrogen is the most important limiting element in tropical soils. The nitrogen content of the soil had increased from 0.2 to 0.26 percent. This was an increase of 26.08 percent in the soil nitrogen content. After 74 months of legume oversowing Hoplinson (1968) cited by Skerman (1988) observed an increment in soil nitrogen from 0.163 to 0.248 percent. Wilson et al. (1982) cited by Abubeker (1997) reported that over a two years period, planting of legumes had increased the soil nitrogen by 34.27 percent. The results are therefore in close agreement to those reported by other authors.

The organic carbon content of the soil in the oversown treatments was also higher than the soil under the control treatment. When the study was started in 1992 the organic matter content was 2.2 percent and after 7 years of oversowing it reached 3.41percent, which was an increment of 55 percent. This was possible because the treatments were left unclipped and this made possible the incorporation of plant material into the soil. The results obtained agrees with that of Hoplinson (1968) cited by Skerman (1988) who reported change in organic carbon from 1.85 to 2.96 percent after 74 months of oversowing. This was an increment of 60 percent.

In a similar manner the CEC, exchangeable sodium and magnesium and available phosphorous increased significantly under the oversown treatments. Therefore this study has shown the potential of legumes in improving rangeland soil fertility status.

5.2 Biomass product

The biomass production in the dry season ranged from 0.94 to 1.75 t/ha DM. The results obtained agree with the finding of Kakengi (1998), which was 0.32 to 1.97 t/ha DM from the same region. The biomass production found from the oversown treatments was higher than that reported by Otsyina et al. (1994) who got an average DM yield of 1.5 t/ha during the dry season from the conserved fodder banks in Shinyanga region. In the dry season the oversown treatments were higher than the control by 72.34 percent for *C. pubescence*, 86.17 percent for *S. hamata*, 79.78 percent for *M. atropurpureum* and 76.59 percent for *C. ternatea* oversown treatments.

The wet season biomass production ranged from 1.25 to 1.79 t/ha. This falls in the range reported by Shem (1996) who got DM production of 0.9 to 5.4 t/ha during the wet season. During this season, the oversown treatments were higher than the control treatment by 20.8, 43.2, 36.0, and 29.6 percent for *C. pubescence*, *S. hamata*, *M. atropurpureum* and *C. ternatea* oversown treatments respectively. The difference in biomass production between years was not significantly different.

The biomass production obtained in this study was low. However, the DM production of the oversown treatments were higher in both the dry and wet seasons than the control. This was evidence that oversowing had improved the DM productivity.

5.3 Evaluation of the nutritional quality of the oversown pasture

5.3.1 Dry season

In the dry season the CP content ranged from 30 g/kg DM for the control treatments to 44 g/kg DM for the treatments oversown with *Clitoria ternatea*. Though the legumes were not found in the dry season, the stem probably contributed for higher CP content of the oversown treatments. The minimum crude protein content required for the proper functioning of the rumen microorganisms is more than 70 g/kg DM percent (McDowell, 1972; Van Soest, 1994). The observed CP content of both the natural and the oversown treatments was therefore lower than the required amount. However, the results obtained with the oversown treatments were promising as they were all higher than the control.

The observed lower CP content falls within the lower range of 20-70 g/kg DM of most tropical grasses in the dry season (Skerman and Riveros, 1990). Therefore in the dry season the forages can not provide enough ammonia for ruminal microorganisms.

Oversowing natural pasture with *C. ternatea*, *S. hamata* and *M. atropurpureum* had improved the CP content by 49.5 percent, 26.6 percent and 22.9 percent respectively. As mentioned earlier, *C. pubescence* was not found in the treatment plots. Though statistically not significant, samples from *C. pubescence* oversown treatment had 17.8 percent more crude protein content than the control. This could be from the residual effect that was carried on to this season. The CP results obtained from this study falls within the lower CP range of most tropical dry season grasses which was reported to range from 20-70 g/kg DM (Skerman and Riveros, 1990). An earlier study conducted during the dry season by Kakengi (1998) showed average CP values ranging from 22 g/kg to 64 g/kg DM. Rubanza (1999), from the same region, reported CP range of 16.39 to 27.24 g/kg DM for the dry season forage. Despite the lower CP content observed from the oversown treatments, they were higher than the natural pasture and the conserved plots ('*Ngitile*') which were reported to range between 30 to 40 g/kg DM (Otsyina *et al*, 1994). The results obtained were also higher than what matured tropical grasses are expected to have which is about 30 g/kg DM or less (McDowell, 1982; Skerman, 1988) and Crowder and Chheda (1982) who observed 10 to 20 g/kg DM at the end of the dry season.

The cell wall component (NDF) ranged from 768.7 g/kg DM to 797.3 g/kg DM for *C. ternatea* and *C. pubescence* oversown treatments respectively. The NDF content of the *C. ternatea* oversown treatment was lower by 2.48 percent than the control. Though not statistically different NDF of *M. atropurpureum* was lower by 1.21 percent than the control treatment. The results obtained from this study were close to those reported by McDonald *et al.* (1995) for poor quality grass hay which was 741 g/kg DM and that of Van Soest (1994) who reported a range of NDF for different grass hays between 640 g/kg DM to 720 g/kg DM. Chenyambuga (1994) obtained NDF content of 807 g/kg DM. The results obtained also agree with the results from the same area by Kakengi (1998) and Rubanza (1999). Kakengi (1998) reported NDF values of 512 to 762 g/kg DM and Rubanza (1999) found a range of 702 to 725 g/kg DM. NDF content of 761 g/kg DM was also reported by Mero (1997) for *Cenchrus ciliaris* hay.

The ADF results obtained ranged from 500 to 522 g/kg DM for *C. ternatea* and *C. pubescence* oversown treatments respectively. The ADF fraction for *S. hamata* oversown treatments, which was 520.8 g/kg DM, was higher than the others. These results fall in a range reported from the same area during the dry season by Rubanza (1999). The researcher found ADF range of 497 to 573 g/kg DM. An earlier study conducted in the same region by Kakengi (1998) found ADF range of 403 to 505 g/kg DM. The results obtained are also similar to those reported by Chenyambuga (1994) who found ADF content of 509 for natural pasture hay. Van Soest (1994) gave ADF range of 360 to 410 g/kg DM for different types of grass hays. McDonald *et al.* reported 452 g/kg DM for poor quality grass hay.

The ADL content ranged from 476 to 492 g/kg DM for *C. ternatea* oversown and the natural treatments respectively. A study conducted by Rubanza (1999) reported ADL content ranging from 119 to 205 g/kg DM during the dry season. Chenyambuga (1994) found ADL content of 89 g/kg DM for natural pasture hay. Van Soest (1994) reported ADL range of 60 to 80 g/kg DM for grass hay.

Generally the cell wall content obtained were higher for both oversown and natural pasture treatments. This was because in mature plants the proportion of the stem to leaf is high. The high cell wall content values reflects the extent of cell wall build up as the dry season progresses.

The variation in NDF and ADF found in this study and those reported by other workers could be due to the stage of maturity, soil type, plant species and climate

(Crowder and Chheda, 1982; Van Soest, 1994). The ADL results reported in this study were higher compared to those of other workers. Several factors could have contributed to this variation. One reason is variation in sample type. In the field these samples were taken at the peak of the dry season. At this period stemy plants had dominated the pasture as they had shaded off their leaves. Contamination with soil particles, which could have increased silica content (Crowder and Chheda, 1982), might have contributed to the higher values, as it was dusty and windy during this period.

5.3.2 Wet season

5.3.2.1 Natural and mixed samples

As it was shown in Table 7, the CP content of the mixed samples ranged from 43.0 to 68.8 g/kg DM for the control and *C. ternatea* oversown treatments respectively. The oversown legumes had improved the CP content by 60.0, 38.8 and 28.8 percent for *C. ternatea*, *M atropurpureum* and *S. hamata* oversown treatments respectively. This improvement was obtained when the percent biomass composition of the legumes was 4.92, 4.99 and 5.68 percent for *C. ternatea*, *S. hamata* and *M. atropurpureum* oversown treatments respectively. The other contributing factor for improved CP could be the influence of the legumes on the soil nutrient status. A study conducted by Vicentre-chander *et al* (1953) cited by Skerman *et al.* (1988) reported rise of CP by 47.5 percent when the proportion of *Pueraria phaseoloides* was 60 percent in molasses grass (*Melinis minutiflora*). Though the proportion of legumes was not given, a study by Rukanda and Lwoga (1981) showed a mean CP increment of 12 percent when *M. atropurpureum* and *S. guyanensis* were oversown in *Themeda-Hayparrhenia* dominated natural grassland at the Sokoine University of Agriculture, the then Faculty of Agriculture, Forestry and Veterinary Science, Morogoro.

The CP contents of the natural pastures in g/kg DM were 43 for the control treatment, 49, 49.1, 55.4 and 55.3 for treatments oversown with *C. pubescence, M. atropurpureum, S. hamata* and *C. ternatea* respectively (Table 7). Natural pastures associated with *C. ternatea, S. hamata, M atropurpureum* and *C. pubescence* showed higher CP contents than the control treatment by 28.6, 28.8, 14.2 and 14.0 percent respectively. The relatively higher CP obtained was due to the benefits that the associated grasses got from the nitrogen fixed by the oversown legumes and higher organic matter incorporated to the soil as the control treatment had lower nitrogen and organic matter content than the oversown treatments. Treatments oversown with *C. pubescence*, though the legumes had disappeared, had higher CP content than the natural pasture from the control treatment. This could be because of the residual effect of the legume from previous years. The CP values reported by Gohl (1981) of 67 g/kg DM for 8 weeks grass was higher than the one found in this study. The results that were reported by Mero (1997) of 51 g/kg DM for *Cenchrus ciliaris* hay agree to what this study came up with. The difference in CP with Gohl (1981) was probably due to the stage of growth. The results obtained in this study also agrees with that of Crowder and Chheda (1982). They reported CP content of grasses ranging from 40 to 60 g/kg DM after 3 to 5 months of uninterrupted growth.

The mixed samples had EE content of 12 to 23 g/kg DM (Table 7). The results obtained are in agreement with those of Gohl (1981) who reported 17 to 26 g/kg DM for the EE content of grasses. *C. ternatea* increased the EE content of the treatment by 22.11 percent.

The cell wall component ranged from 665 to 704 g/kg DM for the natural pasture from *C. ternatea* oversown treatment and the control treatment respectively. For the mixed samples it ranged from 659 to 704 g/kg DM for the control and *M. atropurpureum* oversown treatments respectively. The results are in agreement with the range given by Van Soest (1994) which was 640 to 700 g/kg DM.

Mixed samples from *C. ternatea* oversown treatments were higher in CP content by 15.2 and 4.9 percent than *S. hamata* and *M. atropurpureum* oversown treatments respectively. This was associated with the relatively higher CP content of *C. ternatea*, which was 151 g/kg DM than the other oversown legumes. *C. ternatea* associated pasture showed 3.4 and 2.6 percent higher NDF than *M. atropurpureum* and *S. hamata* associated pasture respectively.

5.3.2.2 Natural pasture and the legume species

The oversown legumes were higher in their CP content than the natural pasture. *C. ternatea* was higher by 253.3 percent, *S. hamata* by 142.8 percent and *M. atropurpureum* by 230.5 percent. The NDF content of the natural grasses were higher compared to the oversown legumes. On the other hand the ADL contents of the legumes were higher than the grasses. These results agree with those reported by Gohl (1981) and Mero (1997).

The CP content of *C. ternatea*, which was 152 g/kg DM, was higher than the other oversown legumes. The results obtained fall in the range of 150 to 255 g/kg DM values reported by FAO (1994). Several workers reported different results for CP content of *S. hamata*. Malcala and Kiflewahid (1996) found 100 g/kg DM, Cloti *et al* (1999) 85 g/ kg DM and FAO (1995) reported 173 g/kg DM. The results of this study, 104 g/kg DM, fall in the range of CP reported by these authors. *M. atropurpureum* had CP content of 142 g/kg DM which is in agreement with 16 weeks age result (143 g/kg DM) reported by FAO (1994). Millford (1967) cited by FAO (1994) found 168 g/kg DM. The difference observed could be due to the stage of growth, soil type, soil nutrient and climate. The NDF content was 543 g/kg DM, 521 g/kg DM and 486 g/kg DM for *S. hamata*, *M atropurpureum* and *C. ternatea* respectively.

5.4 Feed quality between seasons

As it would be expected, the wet season feed, for both the control and oversown treatments showed higher nutritional quality than the dry season feed. Particularly the cell wall content was very low and protein content was high for the wet season feed. McDowell, (1972) and Payne (1990) observed the same trend for forage nutrient content between season and reported that the wet season forage had higher nutritional quality than the dry season forage samples.

5.5 Dry mater and organic matter digestibility

5.5.1 DM and OM digestibility of the dry season pasture

The *in vitro* DM digestibility results ranged from 231.5 g/kg DM to 396.1 g/kg DM for *C pubescence* and *C. ternatea* oversown treatments respectively. The OM digestibility ranged from 304 to 425 g/kg DM for the control and *C. ternatea* oversown treatments respectively. The DM digestibility results obtained from this study agree with that of Crowder and Chheda (1972) who reported DM digestibility of less than 400 g/kg DM for the dry season forage. The same authors reported OM digestibility of 449 g/kg DM for *Andropogon gayanus* hay and 396 g/kg DM for *Hyparrhenia rufa* herbage. Digestibility of a plant can range from 450 to 850 g/kgDM depending on the stage of maturity and season (Van Soest, 1994).

The oversown treatments showed higher DM and OM digestibility than the natural pasture. The DM digestibility has increased by 65.6 percent, 58.4 percent, 38.7 percent and 6.4 percent for treatments oversown with *C. ternatea*, *S. hamata*, *M. atropurpureum* and *C. pubescence* respectively. During the dry season it was reported that the DM digestibility could be less than 40 percent (Crowder and Chheda, 1982). Though the results obtained from this study do fall in this category, they still had influenced the natural pasture, as they were all higher in DM digestibility. Though statistically not significant, samples from *C. pubescence* had higher DM digestibility than the natural pasture. As the legume did not exist, the difference in the DM digestibility could be the residual effect as explained earlier in this chapter. Similarly the organic matter digestibility has increased by 39.9 percent, 23.6 percent, 15.7 percent and 4.8 percent for the treatments oversown with *C. ternatea*, *S. hamata M. atropurpureum* and *C. pubescence* respectively.

The low digestibility values obtained could be due to the high cell wall build up coupled with low CP content of the dry season forages. When the digestibility of forages is poor, rumen evacuation will be lowered hence low intake (Van Soest, 1994) resulting in poor animal productivity.

5.5.2 DM and OM digestibility of the wet season natural and mixed pastures

The DM digestibility of the natural pasture ranged from 419.9 to 435.7 g/kg DM. The DM digestibility did not statistically differ among different treatments. The OM digestibility of the natural pasture ranged from 456 to 477 g/kg DM. The DM and OM digestibility results obtained from this study were lower but were comparable with the lower range of digestibility results reported by Crowder and Chheda (1982) for tropical pasture, which was between 400 to 700 g/kg DM.

The DM digestibility of the mixed samples rangeed from 419.9 g/kg DM to 478.3 g/kg DM for the control and *C. ternatea* oversown treatments respectively. The organic matter digestibility results of mixed samples ranged from 457.4 g/kg DM for the control treatment to 506.6 g/kg DM for treatments oversown with *M. atropurpureum*. In the wet season *C. ternatea*, *M. atropurpureum* and *S. hamata* increased the DM digestibility by 13.9, 13.9 and 6.52 percent and they had also increased the OM digestibility by 8.0, 10.8 and 6.2 percent respectively. Rukanda and Lwoga (1981) reported an increment of 7 percent in DM digestibility as a result of oversowing *M. atropurpureum* and *S. guyanensis* on *Themeda-Hyparrhenia* dominated natural pasture.

5.5.3 DM and OM digestibility of the oversown legumes

As it was shown in Table 12, the DM digestibility of the oversown legumes in g/kg DM were 534, 484 and 460 for *S. hamata*, *M. atropurpureum* and *C. ternatea* respectively. Among the oversown legume species, *S. hamata* had higher DM and OM digestibility than *C. ternatea* and *M. atropurpureum*. It was higher in DM digestibility by 10.3 percent and 16.0 percent than *M atropurpureum* and *C. ternatea* respectively. The OM digestibility was higher by 11.9 percent from *M. atropurpureum* and by 4.5 percent from *C. ternatea*.

The DM digestibility of *S. hamata* obtained from this study was similar to that reported by FAO (1995) for 120 days old pasture which was 527 g/kg DM. However it differed with that reported by Skerman (1988), which was 600 g/kg DM. The OM digestibility was found to be 572 g/kg DM. These results were lower than those reported by Skerman (1988) which was 650 g/kg DM. The variation observed could be because of stage of maturity, soil type, soil nutrient and climate. *M. atropurpureum* showed DM digestibility of 484 g/kg DM and OM digestibility of 512 g/kg DM. The DM and OM matter digestibility results obtained agree with those reported by FAO (1994), which were 504 and 534 g/kg DM respectively.

5.6 Season comparison

As it would be expected the wet season samples were higher in both dry matter and organic matter digestibility than the dry season samples. As plants mature, the cell wall component increases *i.e.* lignification of plant cell wall (Van Soest, 1994). The amount and chemical composition of fiber are important factors in affecting digestibility. However, the fiber fraction has the greatest influence (McDonald *et al*, 1995). When they are found in higher concentration, digestibility of forage will be lowered as was observed from this study. Deficiencies of important nutrients can also reduce the digestibility of the feed. As the plant cell wall increases the nutrient content particularly the CP content, which is critical for microbial activity, will be significantly reduced resulting in poor digestibility. The CP content obtained was lower than the minimal CP required by rumen microorganisms hence, reduced digestibility.

5.7 Degradability and degradation characteristics

5.7.1 Dry season degradability and degradation characteristics

The potential degradability of the dry season forage samples ranged from 492.0 to 600.6 g/kg DM. The results obtained are in agreement with those of Kakengi (1998) who found degradability of 376 to 609 g/kg DM during the dry season in the same region. The results found from this study also agree with those documented by Rubanza (1999). He reported potential degradability of dry season forages ranging from 511 to 613 g/kg DM. In the dry season the forages had already attained maximum maturity and were characterized by high proportion of non-soluble material as is shown by the high ADL and low CP content (Table 6). Highly lignified forage tissues resist ruminal microbial degradation (Ørskov and Ryle, 1990; Van Soest, 1994) hence lower digestibility of the dry season forages.

In the dry season though statistically not different, the oversown treatments were higher in 48 hrs degradability than the natural pasture. The water-soluble fraction of the forages were higher from the control treatment by 133.1, 125.2, 113.1 and 108.7 percent for *S. hamata*, *C. ternatea*, *M. atropurpureum* and *C. pubescence* oversown treatments respectively. The potential degradability of the natural pasture had increased by 22.1 percent, 18.9 percent, 17.4 percent and 16.4 percent for treatments oversown with *C. ternatea*, *M. atropurpureum*, *S. hamata* and *C. pubescence* respectively. The degradation rate constant did not differ much among treatments.

The oversown treatments had better potential degradability than the natural pasture. The improvement in degradability could be due to the relatively higher CP content the oversown treatments had as compared to the natural pasture. Therefore from this study it was found that the oversown legumes had improved the degradability of the pasture.

5.7.2 Degradability and degradation characteristics of the wet season samples

The potential degradability of the natural pasture ranged from 714 to 750 g/kg DM and that of mixed samples ranged between 734 to 753 g/kg DM. *C. ternatea* mixed samples had higher water soluble fraction and potential degradability by 14.8 and 5.1 percent respectively than the natural pasture from the same treatment. Natural pasture from *S. hamata* oversown treatments had 6.0 percent higher 48 hrs degradability than the control treatment.

Mixed samples from *S. hamata* and *M. atropurpureum* oversown treatments were higher in 48 hrs degradability by 11.5 and 6.4 percent respectively. The potential degradability of treatments oversown with *S. hamata*, *M atropurpureum* and *C.*

pubescence were higher than the natural pasture by 5.5, 5.5 and 3.8 percent respectively. Similarly the water-soluble fractions for oversown treatments were higher than the control treatment by 9.3 percent for *S. hamata*, 17.5 percent for *M. atropurpureum* and 20.3 percent for *C. ternatea* oversown treatments.

The potential degradability results obtained from the natural and mixed samples are comparable with those of Shem (1996), who reported degradability of 700 g/kg DM for wet season samples from the same region. The small variations observed could be attributed to difference in the stage of growth. Generally both the natural and mixed forages were good in degradability.

5.7.2.1 Degradability and degradation characteristics of natural pasture and legumes

S. hamata was higher in potential degradability than the natural pasture. Though statistically not different, the oversown legumes were higher in potential degradability as compared to grasses. Smith *et al.* (1991) did degradability of legumes and grass and observed a similar trend as is found in this study. *S. hamata* was higher from the natural pasture in water soluble fraction and rate of degradation by 50.5 and 88.0 percent respectively. *S. hamata* was superior to both *M. atropurpureum* and *C. ternatea* in degradability and degradation characteristics. However, *M. atropurpureum* and *C. ternatea* did not differ significantly.

5.8 Comparison of seasons

The wet season forage was superior to the dry season in 48 hrs degradability, water-soluble fraction and potential degradability (Kakengi, 1998). This had happened due to the relatively higher CP and lower cell wall content of the wet season forage as was explained under the digestibility section.

CHAPTER VI

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

From the results obtained from this study the following concluding remarks could be made: -

- Oversowing with herbaceous forage legumes improved the yield and nutritional quality in terms of CP content and digestibility of the natural grassland in both the dry and wet seasons. The nutritional quality of the associated grasses were also improved. When trying to improve rangeland forage yield and quality, introduction of leguminous forage species should therefore be positively considered.

- As a result of introducing legumes, soil organic carbon, total nitrogen, available phosphorous, cation exchange capacity, exchangeable sodium and magnesium were improved.

- The oversown herbaceous legumes had also improved the species composition of the pasture.

- Among the oversown leguminous species *C. ternatea* had a higher nutritional quality than the others. On the other hand *M. atropurpureum* had better adaptability and *S. hamata* was better in degradability and degradation characteristics. *C. pubescence* had disappeared because it was less competitive. From these results it is clear that *C. ternatea* and

M. atropurpureum were better than the other oversown leguminous species in adaptability and in the role they play in improving the nutritional quality of natural grasslands.

➢ The nutritional quality of the wet season forage was higher than the dry season forage.

6.2 Recommendations

- Herbaceous forage legumes tend to shade their leaves during the early part of the dry season. Therefore farmers could be encouraged to conserve the forage in the form of hay.

- Grazing management as part of the '*Ngitile*' needs to be considered so as to ensure persistence of the legumes.

- The performance of herbaceous legumes changes with time. Therefore, frequent monitoring and evaluation of their performance over time will give more information and room for timely interventions.

- Different oversowing methods can also affect the performance of legumes. Therefore evaluation of different methods should also be considered in order to come up with the best method for a particular species.

- Adoption of the technology is influenced by the availability of seeds. Establishment of seed multiplication units is important to ensure sustainable seed supply.

- The herbaceous forage legumes shade off their leaves during the early stages of the dry season and this makes the nutritional quality of the late dry season forage remain poor. This suggests that besides the herbaceous legumes, there is a need to evaluate some evergreen leguminous species such as multipurpose trees and shrubs, which can persist throughout the dry season.

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APPENDICES

Appendix 1: Species composition of the oversown and the control treatments

Treatment	
Oversown	Control
Aristida adscensionis	*Aristida adscensionis*
Bidens pilosa	*Bidence pilosa*
Branchiaria serrifolia	*Cenchrus ciliaris*
Cassia sp	*Chloris roxburghiana*
Cenchrus ciliaris	*Commelina spp*
Chloris gayana	*Cynodon dactylon*
Chloris roxburghiana	*Digitaria spp*
Comelina benghedensis	*Eragrostis tenuifolia*
Comelina sp	*Hyperrhenia rufa*
Corchorus sp	*Indigofera sp*
Crotalaria sp	*Neonotonia loghitii*
Cynodon dactylon	*Rhynchelytrum repens*
Dactyloctenium aegyptium	*Sida spp*
Dicanthium annulatum	*Solanum inconum*
Digitaria sp	*Spermacoce sp*
Eragrostis horizontalis	*Tephrosia sp*
Eragrostis rigidior	*Tridax procumbens*
Eragrostis tenuifolia	*Urochloa pullulans*
Erlangea cordifolia	
Hetropogon contortus	
Hyperrhenia rufa	
Indigofera sp	
Ipomoea spp	
Launaea cornuta	
Lencas martinicensis	
Monechma debile	
Neonotonia loghitii	
Neonotonia spp	
Panicum Maximum	
Rhynchelytrum repens	
Rotboellia exaltata	
Setaria pallide fusca	
Setaria sphacelata	
Setaria spp	
Setaria verticillata	
Sida spp	
Solanum inconum	
Solanum sp	
Spermacoce sp	
Tephrosia sp	
Tribulus terrestris	
Tridax procumbens	
Urochloa pullulans	

Appendix 2: ANOVA table for CP, EE, NDF, ADF, ADL and ash for the Dry season

Dependent Variable: CP

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	1.75	0.58	1.92	0.1585
PLOT	4	8.96	2.24	7.38	0.0008
BLOCK*PLOT	12	5.15	0.43	1.41	0.2381
Error	20	6.07	0.30		
Corrected Total	39	21.92			

R-Square	C.V.	Root MSE	CP Mean
0.72	15.05	0.55	3.66

Dependent Variable: EE

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	0.12	0.04	10.48	0.0002
PLOT	4	1.16	0.29	77.83	0.0001
BLOCK*PLOT	12	0.12	0.01	2.70	0.0242
Error	20	0.07	0.01		
Corrected Total	39	1.47			

R-Square	C.V.	Root MSE	EE Mean
0.95	7.89	0.06	0.77

Dependent Variable: NDF

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	14.48	4.83	0.91	0.45
PLOT	4	36.46	9.11	1.72	0.1852
BLOCK*PLOT	12	132.06	11.01	2.08	0.0717
Error	20	106.01	5.30		
Corrected Total	39	289.02			

R-Square	C.V.	Root MSE	NDF Mean
0.63	2.94	2.30	78.33

Dependent Variable: ADF

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	42.21	14.07	9.00	0.0006
PLOT	4	27.45	6.86	4.39	0.0104
BLOCK*PLOT	12	137.11	11.43	7.31	0.0001
Error	20	31.26	1.56		
Corrected Total	39	238.04			

R-Square	C.V.	Root MSE	ADF Mean
0.87	2.44	1.25	51.25

Appendix 2 Continued

Dependent Variable: ADL

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	192.38	64.13	1.19	0.3382
PLOT	4	127.86	31.96	0.59	0.6710
BLOCK*PLOT	12	654.97	54.58	1.01	0.4718
Error	20	1076.10	53.80		
Corrected Total	39	2051.32			

R-Square	C.V.	Root MSE	ADL Mean
0.48	15.57	7.34	47.11

Dependent Variable: ASH

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	4.76	1.59	33.34	0.0001
PLOT	4	27.41	6.85	143.91	0.0001
BLOCK*PLOT	12	70.28	5.86	122.99	0.0001
Error	20	0.95	0.05		
Corrected Total	39	103.41			

R-Square	C.V.	Root MSE	ASH Mean
0.99	1.99	0.22	10.95

Appendix 3: ANOVA table for CP, EE, NDF, ADF, ADL and ash for the wet season natural and mixed samples.

Dependent Variable: CP

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	1.44	0.48	3.92	0.0135
PLOT	4	33.44	8.36	68.35	0.0001
TYPE	1	11.94	11.94	97.57	0.0001
BLOCK*PLOT	12	5.74	0.48	3.91	0.0003
BLOCK*TYPE	3	0.26	0.09	0.70	0.5582
PLOT*TYPE	4	4.73	1.18	9.67	0.0001
Error	52	6.36	0.12		
Corrected Total	79	63.90			

R-Square	C.V.	Root MSE	CP Mean
0.90	6.45	0.35	5.42

Dependent Variable: EE

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	0.32	0.11	7.50	0.0003
PLOT	4	10.82	2.70	191.45	0.0001
TYPE	1	0.18	0.18	12.44	0.0009
BLOCK*PLOT	12	3.42	0.29	20.19	0.0001
BLOCK*TYPE	3	0.05	0.02	1.11	0.3541
PLOT*TYPE	4	0.60	0.15	10.58	0.0001
Error	52	0.73	0.01		
Corrected Total	79	16.11			

R-Square	C.V.	Root MSE	EE Mean
0.95	6.36	0.12	1.87

Appendix 3: Continued

Dependent Variable: NDF

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	49.33	16.44	8.05	0.0002
PLOT	4	230.76	57.69	28.25	0.0001
TYPE	1	0.09	0.09	0.04	0.8329
BLOCK*PLOT	12	140.85	11.74	5.75	0.0001
BLOCK*TYPE	3	52.02	17.34	8.49	0.0001
PLOT*TYPE	4	20.45	5.11	2.50	0.0534
Error	52	106.20	2.04		
Corrected Total	79	599.71			

R-Square	C.V.	Root MSE	NDF Mean
0.82	2.09	1.43	68.23

Dependent Variable: ADF

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	20.80	6.93	3.56	0.0202
PLOT	4	183.48	45.87	23.58	0.0001
TYPE	1	3.98	3.98	2.04	0.1587
BLOCK*PLOT	12	131.03	10.92	5.61	0.0001
BLOCK*TYPE	3	21.98	7.33	3.77	0.0160
PLOT*TYPE	4	9.29	2.32	1.19	0.3246
Error	52	101.18	1.94		
Corrected Total	79	471.74			

R-Square	C.V.	Root MSE	ADF Mean
0.79	3.49	1.39	39.95

Dependent Variable: ADL

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	9.06	3.02	2.26	0.0922
PLOT	4	40.96	10.24	7.66	0.0001
TYPE	1	3.19	3.19	2.39	0.1285
BLOCK*PLOT	12	28.62	2.38	1.78	0.0756
BLOCK*TYPE	3	5.04	1.68	1.26	0.2983
PLOT*TYPE	4	3.14	0.79	0.59	0.6726
Error	52	69.49	1.34		
Corrected Total	79	159.51			

R-Square	C.V.	Root MSE	ADL Mean
0.56	21.42	1.16	5.40

Dependent Variable: ASH

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	11.28	3.76	2.26	0.0925
PLOT	4	15.21	3.80	2.28	0.0726
TYPE	1	1.73	1.73	1.04	0.3121
BLOCK*PLOT	12	61.68	5.14	3.09	0.0024
BLOCK*TYPE	3	2.62	0.87	0.52	0.6674
PLOT*TYPE	4	2.73	0.68	0.41	0.8002
Error	52	86.56	1.66		
Corrected Total	79	181.82			

R-Square	C.V.	Root MSE	ASH Mean
0.52	11.87	1.29	10.87

Appendix 4: ANOVA for CP, EE, NDF, ADF, ADL and ash for the wet season natural sample and the oversown legumes samples.

Dependent Variable: CP

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	5.03	1.68	6.81	0.0009
PLOT	4	53.05	13.26	53.83	0.0001
TYPE	1	758.67	758.67	3079.72	0.0001
BLOCK*PLOT	12	4.07	0.34	1.38	0.2186
BLOCK*TYPE	3	3.67	1.22	4.97	0.0053
PLOT*TYPE	2	56.29	28.15	114.26	0.0001
Error	38	9.36	0.25		
Corrected Total	63	1148.09			

R-Square	C.V.	Root MSE	CP Mean
0.99	6.11	0.50	8.13

Dependent Variable: EE

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	0.03	0.01	0.38	0.7655
PLOT	4	6.70	1.68	61.51	0.0001
TYPE	1	6.79	6.79	249.10	0.0001
BLOCK*PLOT	12	1.22	0.10	3.73	0.0009
BLOCK*TYPE	3	0.29	0.10	3.58	0.0226
PLOT*TYPE	2	9.68	4.84	177.60	0.0001
Error	38	1.04	0.03		
Corrected Total	63	30.99			

R-Square	C.V.	Root MSE	EE Mean
0.97	7.64	0.17	2.16

Dependent Variable: NDF

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	15.91	5.30	3.51	0.0244
PLOT	4	183.69	45.92	30.35	0.0001
TYPE	1	2779.78	2779.78	1837.32	0.0001
BLOCK*PLOT	12	42.79	3.57	2.36	0.0222
BLOCK*TYPE	3	35.56	11.85	7.83	0.0003
PLOT*TYPE	2	60.25	30.13	19.91	0.0001
Error	38	57.49	1.51		
Corrected Total	63	4531.41			

R-Square	C.V.	Root MSE	NDF Mean
0.99	1.98	1.23	62.05

Dependent Variable: ADF

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	6.52	2.17	1.38	0.2644
PLOT	4	136.86	34.21	21.69	0.0001
TYPE	1	157.83	157.83	100.06	0.0001
BLOCK*PLOT	12	58.48	4.87	3.09	0.0039
BLOCK*TYPE	3	1.96	0.65	0.41	0.7440
PLOT*TYPE	2	59.82	29.91	18.96	0.0001
Error	38	59.94	1.58		
Corrected Total	63	649.92			

R-Square	C.V.	Root MSE	ADF Mean
0.91	3.27	1.26	38.42

Appendix 4: continued

Dependent Variable: ADL

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	2.83	0.94	0.50	0.6825
PLOT	4	24.86	6.22	3.31	0.0202
TYPE	1	89.33	89.33	47.55	0.0001
BLOCK*PLOT	12	10.59	0.88	0.47	0.9200
BLOCK*TYPE	3	2.82	0.94	0.50	0.6842
PLOT*TYPE	2	4.39	2.19	1.17	0.3216
Error	38	71.39	1.88		
Corrected Total	63	220.53			

R-Square	C.V.	Root MSE	ADL Mean
0.68	20.86	1.37	6.57

Dependent Variable: ASH

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	1.32	0.44	1.41	0.2552
PLOT	4	31.14	7.80	24.86	0.0001
TYPE	1	28.66	28.66	91.51	0.0001
BLOCK*PLOT	12	13.51	1.13	3.59	0.0013
BLOCK*TYPE	3	2.94	0.98	3.12	0.0370
PLOT*TYPE	2	77.11	38.55	123.09	0.0001
Error	38	11.90	0.31		
Corrected Total	63	174.25			

R-Square	C.V.	Root MSE	ASH Mean
0.93	5.36	0.56	10.45

Appendix 5: ANOVA table for 48 hrs degradability and degradation characteristics.

Dependent Variable: 48 hrs degradability

Source	DF	SS	Mean Square	F Value	Pr > F
SAMPLE	15	2350.91	156.73	59.38	0.0001
Error	16	42.23	2.64		
Corrected	31	2393.14			

R-Square	C.V.	Root MSE	DEGRAD Mean
0.98	2.57	1.62	63.22

Dependent Variable: *a*

Source	DF	SS	Mean Square	F Value	Pr > F
SAMPLE	15	768.59	51.244	23.76	0.0001
Error	16	34.50	2.16		
Corrected Total	31	803.09			

R-Square	C.V.	Root MSE	IMD Mean
0.957041	7.15	1.47	20.55

Appendix 5 Continued

Dependent Variable: *a + b*

Source	DF	SS	Mean Square	F Value	Pr > F
SAMPLE	15	2123.84	141.59	74.28	0.0001
Error	16	30.50	1.91		
Corrected Total	31	2154.34			

R-Square	C.V.	Root MSE	PD Mean
0.99	2.03	1.38	67.89

Dependent Variable: *c*

Source	DF	SS	Mean Square	F Value	Pr > F
SAMPLE	15	0.00599452	0.00039963	2.00	0.0905
Error	16	0.00320000	0.00020000		
Corrected Total	31	0.00919452			

R-Square	C.V.	Root MSE	RATCON Mean
0.65	30.11	0.01	0.05

Appendix 6: ANOVA table for IVDM and IVOM digestibility

Dependent Variable: IVDMD

Source	DF	SS	Mean Square	F Value	Pr > F
SAMPLE	15	1541.09	102.74	65.53	0.0001
Error	16	25.09	1.57		
Corrected Total	31	1566.18			

R-Square	C.V.	Root MSE	IVDMD Mean
0.98	2.98	1.25	42.05

Dependent Variable: IVOMD

Source	DF	SS	Mean Square	F Value	Pr > F
SAMPLE	15	1487.12	99.14	31.95	0.0001
Error	16	49.65	3.10		
Corrected Total	31	1536.77			

R-Square	C.V.	Root MSE	IVOMD Mean
0.97	3.85	1.76	45.72

Appendix 7: ANOVA table for biomass production for the year 1999 and 2000

Dependent Variable: BIOM 1999

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	0.05	0.02	1.07	0.3971
PLOT	4	1.78	0.44	26.39	0.0001
Error	12	0.20	0.02		
Corrected Total	19	2.04			

R-Square	C.V.	Root MSE	BIOM2 Mean
0.90	8.48	0.13	1.53

Dependent Variable: BIOM 2000

Source	DF	SS	Mean Square	F Value	Pr > F
BLOCK	3	0.33	0.11	2.17	0.1445
PLOT	4	0.69	0.17	3.35	0.0464
Error	12	0.62	0.05		
Corrected Total	19	1.64			

R-Square	C.V.	Root MSE	BIOM1 Mean
0.62	14.41	0.23	1.57