IMPROVEMENT OF NATURAL PASTURES (*RWEYA* LAND) BY OVERSOWING WITH LEGUMINOUS PLANT SPECIES IN BUKOBA DISTRICT, TANZANIA

BY

CALEB VICTOR MWITA

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT
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ABSTRACT

A study was conducted in three *rweya* sites at Maruku Agricultural Research and Development Institute, Bukoba. Five leguminous plant species (*Centrosema pubescens*, *Desmodium intortum*, *Macroptilium atropurpureum*, *Clitoria ternatea* and *Puereria phaseoloides*) were oversown into natural pastures to assess their influence on forage dry matter yield, nutritive value and soil fertility. Sites were selected based on differences in soil fertility. These were; one with high soil fertility, two with medium soil fertility and three with poor soil fertility. Two soil samples were taken at each site for analysis, one before oversowing and another eight months after oversowing. Forage samples were also harvested twice, at seven months after oversowing and seven weeks after first harvest. Soil analysis indicated that oversowing improved soil nitrogen and available phosphorus but had no impact on soil organic matter and pH. *Macroptilium atropurpureum* and *C. ternatea* disappeared from site three while *C. pubescens* and *P. phaseoloides* performed well across all sites. In the first harvest the DM yield in all sites ranged between 778.48±162 and 1384.36±162kgDM/ha and its was not significantly different between treatments. In the second harvest, DM yield ranged between 1013.63±184 and 2564.61±188kgDM/ha. This harvest had generally higher DM yields than the first. Generally, the control treatments had lower DM yields than the oversown treatments. The CP content in the first harvest ranged between 4.62±0.29 and 11.28±0.64%. Highest value was observed in *C. pubescens* oversown treatment while the lowest value was observed in the control treatments. In the second harvest, the CP content ranged between 5.44±0.43 and 9.14±0.64%. It was also observed that all oversown treatments had CP values above 6.5%. NDF content in the first harvest ranged between 69.03±1.72 and 74.36±1.26% for oversown treatments and the control treatments it ranged between 74.89±1.72 and 79.68±1.26% in all sites. In the second harvest, NDF content for oversown treatments ranged between 69.6±1.72 and 76.77±1.26% and for the control treatments it ranged between 75.16±1.72 and 78.04±1.26%. The ADF content in the first harvest ranged between 37.22±0.89 and 46.62±0.61 for oversown treatments and the control treatments ranged between 44.57±1.35 and 47.67±0.89%. In the second harvest, ADF values ranged between 40.78±1.35 to 48.85±0.89% and 48.27±1.35 to 50±0.61% for oversown and control treatments respectively. *In vitro* dry matter digestibility in the first harvest ranged between 34.44 to 41.59±3.11% and 28.54±2.13 to 37.27±1.81 for oversown and the control treatments respectively. In the second harvest it ranged between 30±3.11 and 38.74±1.81% and 27.78±2.13 to 32.52±1.81% for the oversown and the control treatments respectively. The *In vitro* organic matter digestibility ranged between 49.93±2.49 to 55.98±3.14% and 42.45±2.49 to 47.46±1.66% for the oversown and control treatments respectively. In the second harvest it ranged between 47.17±2.49 to 52.49±1.66% for the oversown treatments and 41.71±2.49 to 46.12±1.66% for the control treatments. In all harvests the control treatments had lower values than the oversown treatments. It was concluded that, oversowing leguminous plant species into natural pastures improved soil chemical properties and also it increased the nutritive value of natural pastures in terms of higher digestibility values, CP contents and reduced cell wall contents (NDF and ADF). It was also observed that, oversowing had no effect on ash and ADL content of natural pastures.

DECLARATION

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

Signature.......................

Date..22|8|2003...

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ABBREVIATIONS

$	US Dollar
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
Al	Aluminum
ANOVA	Analysis of variance
AOAC	Association of Official Agricultural Chemists
ARDI	Agricultural Research and Development Institute
BS	Base Saturation
C	Carbon
C:N ratio	Carbon to Nitrogen ratio
C_{14}	Carbon 14
Ca	Calcium
CEC	Cation Exchange Capacity
CF	Crude Fibre
cm	centimeter
CP	Crude Protein
DASP	Department of Animal Science and Production
DM	Dry Matter
DMD	Dry Matter Digestibility
EE	Ether Extract
FAO	Food and Agriculture Organisation of United Nations
g	gram
GLM	General Linear Model

ha	Hectare
IVDMD	*In vitro* Dry Matter Digestibility
IVOMD	*In vitro* Organic Matter Digestibility
K	Potassium
Kg	Kilogram
km^2	Kilometre square
LS	Least Squares
m^2	meter square
Mg	Magnesium
Mm	millimeters
Mn	Manganese
N	Nitrogen
Na	Sodium
NDF	Neutral Detergent Fibre
NFE	Nitrogen Free Extract
NORAD	Norwegian Agency for Development and Cooperation
NPN	Non Protein Nitrogen
OM	Organic Matter
OMD	Organic Matter Digestibility
P	Phosphorus
pH	*pouvoir hydrogene*
ppm	parts per million
SE	Standard Error
TSh	Tanzanian shillings

SOM	Soil Organic Matter
SUA	Sokoine University of Agriculture
TAP	Tropical Animal Production

CHAPTER ONE

1.0 INTRODUCTION

The grazing capacity of many rangelands has declined perceptibly on all continents and less desirable plants have rapidly replaced the more palatable and nutritious species (Crowder and Chedda, 1982). A comparable situation is also encountered in regions of East Africa where range development is hampered by low and erratic rainfall, low quality grasses growing on poor soils, lack of water, incidence of diseases and sociological limitations (Mestawet, 2000).

The improvement and conservation of deteriorating rangelands is of great importance to livestock keepers. Rangelands can be improved through different methods including oversowing desirable leguminous plant species into existing indigenous pastures, range seeding and fertilizing, development of watering points and controlled burning (Kidunda, 1996). In rangelands with poor soil fertility, poor bio-diversity and poor forage quality and quantity, it is important to use improvement strategies, which can solve these problems. It is even more important to find means of solving them with least cost so as to make the strategies more adoptable by small-scale farmers who form the majority of livestock keepers in Africa. Oversowing leguminous species in native pasture is among the best low input options in improving rangelands (Mestawet, 2000; Giller, 2001).

Studies done elsewhere indicate that introducing legumes into the native pastures alone increased animal production by up to ten times (Tothill, 1986; Abubeker, 1997). In Ethiopia, Lemma and Abubeker (1995) reported from Bako research station a five-fold increment in live weight gain of Horo bulls grazing on Stylo oversown natural pasture as compared to bulls grazing in sole natural pasture. Improved live weight gains were also reported in other studies e.g. Stylo oversown pasture in Queensland (Skerman *et al*, 1988). Gilland, *et al.*, (1997) reported a 3 year accumulation of 880 kg/ha from steers grazing guinea grass (*Panicum maximum*) oversown with Centro and 660 kg from guinea grass alone in Queensland.

Renovation of native pastures by strip sowing or intersown with *Stylosanthes hamata* resulted in least weight loss of bulls grazing the intersown stand in the dry season in 2 of 3 years and had the greatest live weight gain in the remaining year (Abubeker, 1997).

Legumes are crucial to the balance of nature, for many are able to convert nitrogen gas from the air into ammonia, a readily soluble form of nitrogen, which is utilized by plants (NAS, 1985). In Australia, the fertility increase by legumes has allowed vast areas to be brought into arable cultivation (Crowder and Chedda, 1982).

In nature, the vigorously nodulating strains are usually found in soils where the particular legume specie is native. When man introduces the plant to a region where it has never been grown before, the most effective nitrogen fixing rhizobial strains may be lacking. Thus when a legume is grown for the first time in a new area, it is crucial to ensure that the appropriate rhizobia are likely to be present in the soil (NAS, 1979).

Natives of Kagera region define *rweya* land use type as open natural grassland, fallowed or bushed grassland. It normally occurs between villages, far from home gardens, and consists of permanently uncultivated areas (because of shallow soils or rock outcrops, or steep slopes) and areas with grass fallow (after cultivation of annual crops). In the region, *rweya* is the source forage for livestock. However, like many other African rangelands, it is reported to have very low soil fertility in all aspects (Baijukya and Folmer, 1999). Other important land use types in Kagera are *kibanja*, which is used for perennial crop cultivation such as banana and coffee and *kikamba*, which is used for growing annual crops.

There are strong and obvious differences in soil nutrient status between soils under homestead gardens (i.e. *kibanja* and *kikamba*) and those under grassland fallow or natural vegetation (*rweya*). These differences are man made. In the homestead gardens, there is a recycling and import of organic materials mainly from *rweya*; thus they have thick dark topsoil with high amounts of organic matter, which have been built up in the course of generations. Recycling of household refuse, crop residues and application of farm yard manure, supplemented by grasses from surrounding fallow, has increased the previously low natural fertility of the home gardens (Touber and Kanani, 1994). However, this process meant a gradual export of nutrients from the surrounding land (*rweya*), thus widened the difference. The soil in the present grassland fallow that surrounds the clusters of homestead gardens are subject to impoverishment, in the past times it was due to the removal of the original forest vegetation and subsequent increased leaching process (Milne, 1938). Currently the main cause of low fertility is due to short fallow cycle and continued export of cut grasses (for mulching) from *rweya* to *kibanja* and *kikamba.*

Due to poor soil fertility in *rweya* land, many farmers use annual fodder species found in *kikambas*, around *kibanjas* and roadside grasses to feed livestock especially for zero grazed animals. However, *kikamba* and *kibanja* are specifically used for growing annual and perennial crops and are therefore unavailable during the cropping season. This has negative nutritional implications in livestock as they feed on less nutritive forages found in *rweya* and hence low animal productivity (Lorkeers, 1995).

The *rweya* grassland in Bukoba district is roughly divided into two zones; *Eragrostis/Loudetia* zone or Bukoban system in the east and *Themeda/Hyperrhenia* zone or Karagwe-Ankolean system in the west. Of two, *Eragrostis/Loudetia* (Bukoban system) has the lowest fertility gradient due to parent rock material and high rainfall, which causes heavy leaching (Touber and Kanani, 1994).

For this reason attempts to improve *rweya* land especially *Eragrostis/Hyperrhenia* zone should be made in order to improve not only animal productivity but also help other traditional users such as women who usually plant bambara nuts and sweet potatoes in *rweya* and other stakeholders e.g. pineapple growers and horticultural crop growers. Currently, women have to bulk a lot of weeds from far away in order to lower C:N ratio when making bunds for bambara nuts and sweet potato production.

For any improvement program to be useful to most livestock keepers, it should be simple and cost effective. Experience has shown that, conventional systems of pasture improvement such as use of mineral fertilizer in pasture improvement have not been adopted in Africa. The reasons for this being, poor income to most of the traditional livestock keepers, unavailability and poor germination of seeds (Tesha and Mtengeti, 1995). In Kagera region apart from the mentioned reasons, it has been found that most people cannot use fertilizer in pasture improvement because they would rather use any small amount of fertilizer/manure they have to improve the *kibanja*, which increases banana production, their traditional staple food (KALIDEP, 1997).

It is from this background that, this study aims to use leguminous plant species as an alternative to improve yield and nutritive value of pastures as well as soil fertility.

Justification

A careful observation of the nutrient flows in the farming systems in Kagera region will indicate that there is reduction of *rweya* in terms of size and productivity through new settlements and deterioration of pastures. This causes reduction in the number of grazing cattle, conflict between crop producers and livestock keepers and faster deterioration of *rweya* in terms of soil fertility resulting from shorter fallow cycle (Baijukya and Mwita, 2000). These conditions bring about challenges for both research and development to find ways to increase and sustain productivity of the *rweya*.

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The objective of this study was to investigate the chemical composition of fodder species found in *rweya* and to explore the possibility of using leguminous fodder species to improve both the nutritive value of indigenous pasture species and at the same time improve soil fertility.

Objectives

General objective

To increase animal productivity and biomass production of *rweya* land by oversowing with leguminous plant species.

Specific objectives

- To estimate the chemical composition of natural forages grown on *rweya* before and after oversowing with leguminous plant species
- To estimate DM yield of natural forages grown on *rweya* before and after oversowing with leguminous plant species
- To evaluate the *In vitro* DM and OM digestibility of the forages before and after oversowing with leguminous plant species
- To evaluate the effect of oversowing leguminous plants on soil fertility status

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The *rweya*

In Kagera region, *rweya* (grassland) is valued as an important component of the farming systems (Baijukya and Folmer, 1999). In the past, *rweya* was mainly used for grazing of livestock and cultivation of annual crops. In addition, *rweya* was also used as a source of grass for carpet, thatch, brewing and mulch. Currently new activities such as tree planting, establishment of *kibanja*, and planting of horticultural crops such as pineapples also take place on *rweya* land.

These changes in *rweya* use are a result of many factors such as; increase in human population which has caused land shortage and hence expansion into marginal areas (*rweya*), deterioration of banana fields (*kibanja*) hence introduction of other alternative crops such as root and tubers and maize, and deterioration of coffee prices which has prompted farmers to shift into new crops such as pineapples and other horticultural crops.

For these reasons, *rweya* is becoming unavailable to traditional users (grazing of animals, cultivation of annual crops and collection of thatch grasses etc), which leads to conflicts among users. In addition, recent changes in land policy (from communal ownership to privatization) have led to different *rweya* ownership status, resulting into marginalisation of some user groups such as livestock keepers (Baijukya and Folmer, 1999). The total *rweya* area in Kagera region is 10740 km^2, which is 39.76% of the total land (Table 1).

Table 1: Areas in km^2 x 1000 of rweya in different districts of Kagera region

District	Area	*Rweya* land	% of *rweya*
Bukoba	5.50	1.98	36.0
Karagwe	6.70	2.79	41.6
Ngara	3.70	1.89	51.1
Biharamulo	9.20	2.69	29.2
Muleba	3.40	1.39	40.9
Total	28.5	10.74	39.76

Source: Baijukya and Folmer, (1999).

2. 2 Description of *rweya* grassland

The present *rweya* grassland in Kagera region is believed to be a result of forest clearing for agriculture, hunting, and provision of pasture for livestock. Excavations of iron tools and by using C_{14} dating and pollen analysis confirm that agricultural activities and forest clearance started during early Iron Age (Steenhuijsen Piters, 1999). Soils of the lakeshore have low natural fertility and the organic matter accumulated under forest vegetation must have disappeared when agriculture increased over time thus creating the poor grasslands.

Rweya grassland provides grazing forages of extremely low nutritive value. The natural cover consists of tufted wiry grasses mostly *Eragrostis olivacea*, *Loudetia kagerensis*, and *Hyperrhenia filipendula*. There is also a ground cover of stoloniferous grasses such as *Eragrostis mildbraedi*, *E. olivacea*, and *Digitaria scalarum*. All of these grasses have an excess of phosphate over calcium, which is a bad feature from a nutritional point of view (Maruku station notes, 1960).

Milne (1938) gave an excellent overview of the soil fertility problems of Bukoba District. The author mentioned that there was an unusual degree of infertility of the *rweya*. The stock carrying capacity of the land was low, though the bulk of feed remained large, because only the poorer grasses could flourish even if ample rainfall promoted heavy growth. The deficiency seems to be a general one in all available plant nutrients. Touber and Kanani (1994) also observed the same feature in recent soil investigations. In their report on the status of cations in the Bukoban soils, it was stated that the shortage of Ca, K and Mg in these soils ties in with the practice of planting in burnt turf on the poorer soils as plant ash contains K, Ca and Mg. Perhaps this is an empirical way of getting plant roots and topsoil organic matter sufficiently decomposed to release these nutrients.

Organic matter content of the soils in Bukoban system is higher particularly in the upper subsoils (beyond 20cm depth). It ranges between 4-8% (Touber and Kanani, 1994). However, the organic matter is inert because it is made of very poor grasses and does not therefore indicate higher fertility of *rweya*.

In 1995, a study was conducted to assess the quality of *rweya* soils, grasses and the role of *rweya* on livestock production. The results of the study showed that, '*rweya* topsoils of the Bukoban System were characterized by very to extremely low exchangeable base contents (calcium, magnesium and potassium), an extremely low cation exchange capacity (CEC), a low to very low base saturation, a high to very high aluminum saturation and a moderate to strong acidity (Lorkeers *et al.*, 1996). Phosphorus contents are very variable, but on average extremely high in *rweya* soils'

(Table 2). The higher P level in the Bukoban system is not well explained, but it is thought to be caused by certain rock strata Floor *et al*, (1990) cited by Touber and Kanani, (1994). Alternatively, volcanic ash deposition has been mentioned to cause this high P in the soil (Morbeg, 1974).

Table 2: Topsoil data from Bukoba high rainfall zone

	SOM %	pH	Ptot ppm	Pbray ppm	Ca Meq/10	Mg Meq/10	K Meq/10 r	CEC	BS %	Al. S %
Kibanja plateaus/ upland	5.5	5.7	2147	147	6.1	1.3	0.3	8.5	91	2
Rweya, plateaus/ upland	7.1	5.2	1634	13	-	-	-	1.3	23	51
Rweya, Dip slopes	2.9	5.3	1026	116	-	-	-	1.3	18	66

Source: Lorkeers *et al*, (1996)

2.3 The need to improve *rweya* land use

Thomas (1940) mentions the importance of soil quality for grassland composition and quality. He remarked, "The best grasses grow on the best soils". Soils in Bukoba district are chemically poor to very poor (Lorkeers, *et al* 1996). This is due to the past and present periods of high rainfall and temperatures, which meant an intensive weathering of parent rock and subsequent leaching of released nutrients. Secondly, the rock types in the district, which are mainly Precambrian shales, siltstone, sandstone, quartzite and conglomerates, contain very few nutrient-releasing minerals (Touber and Kanani, 1994). However, both soil parent material (rock types) and soil forming conditions are not uniform throughout the district. For example rainfall distribution ranges from about 2100mm in the east to less than 800mm in the west. This means stronger leaching, but also higher production of organic matter through more vigorous plant growth to the Lake Victoria side, and less leaching, less organic matter towards the drier interior (Touber and Kanani, 1994).

Chemical properties of soils developed in rocks of the Karagwe-Ankolean (Themeda/Hyperrhenia zone) system do not show much contrast among various areas. They have moderate amounts of organic matter in the topsoils diminishing to low levels in the upper subsoil. Levels of nitrogen follow the same trend. On the other hand soils of the Bukoban system (Eragrostis/Loudetia zone) differ in chemical aspects from those in the Karagwe-Ankolean system. They have on the average lower cation exchange capacity, much lower base saturation percentages and higher levels of exchangeable aluminum, higher organic matter, and total phosphorus (Table 2).

Forages growing on *rweya* have extremely low nutritive value; they have deficiency in protein, calcium, copper and cobalt. There is also an imbalance of calcium: phosphate ratio, which is reflected in animal nutrition problems in Bukoba. In general cows in milk do not come on heat and may remain in anoestrus condition for some time after lactation. Heat periods are generally very short and occur at night and sometimes may pass unnoticed by herdsmen. Growing animals take long to mature and lactating cows calve every second year (Lorkeers *et al*, 1996).

Research has shown that, many crops including buckwheat, cowpea, sorghum, velvet beans, maize, sunflower, Irish potatoes, sweet potatoes etc which were planted in *rweya* hardly germinated and of those crops which reached maturity the yield was extremely low (Maruku station notes 1920). Only on heavy applications of manure or compost (25 to 40 tons/acre) could yield acceptable harvest. The same observations are true for sown pasture where yields are very low (personal observation).

Despite having grasses with very poor nutritive value in most critical nutrients (Baijukya and Mwita, 2000), *rweya* grassland is the one, which is mainly used for livestock grazing in Kagera region. Hence a need to improve this grassland is of vital importance for livestock keepers.

2.4 Methods of pasture improvement using legumes

Three low input approaches to pasture improvement using legumes have been recognized as:

- Oversowing legumes into existing pasture
- Replacement of the existing vegetation with a mixture of an improved grass and legume
- Establishment of a legume monoculture (or protein bank) in association with existing pasture or with pasture, which has been improved (t'Mannetje, 1986).

The main objective of including legumes in pastures is attributed to the fact that, it improves fodder quality as forage legumes are rich in N and provide extra source of protein to grazing animals. Through selective grazing, quite a small quantity of legume in the pasture can markedly improve the nutrition of livestock at critical times of the year (Skerman *et al*, 1988). At the sisal research station in Tanga, Tanzania (latitude 5^{0}S) *Puereria phaseoloides* was used as a cover crop growing as an inter-row crop with sisal on a red loam soil over gneiss, it increased the yield of sisal by 48 percent over that of clean weeded, inter-row cultivated crop. In addition to protecting the soil from erosion and being livestock feed, the legume encouraged earlier unfurling of sisal leaves and added 635 kilograms of nitrogen per hectare to the soil, equivalent to the application of 1.4 tons of urea per hectare (Skerman, 1977). At Serere research station, Uganda (lat. 1.^{0}32'N) with an annual bimodal rainfall of 1365mm, the early research on leys was conducted with pure Rhodes grass (*Chloris gayana*). During a three-year ley, mean animal production from this unfertilized grass was 209 kilograms per hectare per year. The inclusion of legumes *Stylosanthes guianensis* and *Centrosema pubescens* increased animal production by 11 to 49 percent Stobbs (1969c) cited by Skerman, (1977).

At Ibadan, Nigeria, the inclusion of *Centrosema pubescens* in a giant star grass (*Cynodon plectostachyus*) pasture on a podzolic soil resulted in significantly higher levels of organic matter and total nitrogen. The legume raised the nitrogen content of the grass from 1.8 to 2.4 percent (Skerman, 1977).

Significant increase in milk production up to 20% has been obtained on grass/legume pastures compared with grass only. 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). The benefits attributed to the presence of forage legume in the pasture have been observed with a range of pastures with different legumes in different ecosystems in the tropics (CIAT, 1992).

When legumes are produced in a mixed sward, there is an improvement of chemical composition of associated grasses. In Puerto Rico, oversowing *Puereria phaseoloides* (Tropical kudzu) into molasses grass (*Melinis minutiflora*) raised the protein level from 4.2% to 8% with 60% legume by weight in the mix (Skerman *et al.*, 1988).

Oversowing natural grassland with leguminous plant species improves the yield as well as performance of grazing animals. In an experiment conducted by Rukanda and Lwoga (1981) for six months by oversowing *M. atropurpureum* and *Stylosanthes guyanensis* in a *Themeda-Hyperrhenia* dominated natural grassland at the Faculty of Agriculture, Forestry and Veterinary science, Morogoro, it was found that oversowing increased total DM yield by 30% and CP by 50%. In the same experiment it was found that, the mean CP content in a period of six months increased by 12% and mean *In vitro* DM digestibility increased by 7% and live weight gain of grazing dairy heifers increased by 112%.

The functions of symbiotic nitrogen fixation by pasture legumes can be summarized as follows: -

- Ability to fix nitrogen from the air gives the legume competitive advantage in association with grasses and weeds.

- The presence of the legume in the forage provides a better diet for livestock because legumes in general have a relatively high feeding value and specifically because nodulated legumes can maintain a higher nitrogen concentration than grasses, particularly in mature forage. Nodulated legumes do not show the rapid dilution of plant nitrogen concentration that occurs when unnodulated legumes and non-legumes are grown with a limited nitrogen supply
- The legume contributes available nitrogen to non-legumes in the sward
- The legumes contributes nitrogen that may be useful during a subsequent period of arable farming (Crowder and Chheda, 1982; Giller,2001).

In selecting legumes for pasture improvement, consideration should be based on yield of good quality fodder, rich in protein and ability to establish and persist well in the sward. Thus the legume must be well adapted to the environment in a given region and must also be compatible with the dominant grasses in the existing pasture. Legumes selected for oversowing must also be able to yield and persist with minimal fertilizer additions, or preferably without their use (Giller, 2001).

As low input approach for pasture improvement, oversowing is the only approach feasible in most of the tropics. The approach is an attractive low-input method but success is dependent on moisture status after sowing and on competition from existing vegetation (Giller, 2001).

In many parts of the tropics, land left to fallow between cropping seasons is grazed by cattle, but ley farming has not been widely adopted in many parts of the tropics Humphreys (1994) cited by Giller, (2001). There is comparatively little research in the tropics in examining the use of planted legume or legume/grass leys for animal production and the restoration of soil fertility.

2.5 Effect of physical factors on legume symbiosis

If uninoculated legume seed is planted in a new environment its nodulation will depend in part on the effectiveness of the plant in its symbiosis with the native *rhizobium* species. It may be compatible and nodulate and develop well, it may be incompatible and fail to nodulate or it may slowly select an effective strain from native *rhizobium* and gradually build up successful population of effective nodules over a period. Thus some tropical legumes such as *Glycine*, *Desmodium* and *Centrosema* may grow much better in their second than in the year of establishment (Skerman, 1977; Crowder and Chheda, 1982).

Apart from the effectiveness of *Rhizobium*, other physical factors affecting symbiosis are air, moisture, temperature and soil reaction. Well-structured soil allows free access of air and has a positive effect on the activity of rhizobia. The rhizobia are sensitive to the moisture content of the soil. They are sensitive to excessive drying while excessive water may limit aeration and hence survival of bacteria. Maximum growth and nodulation occur in soil water content between 75-85% of its water holding capacity. Optimum light intensity is essential for maximum nodulation and nitrogen fixation. A decrease of temperature below 5% of optimum soil temperature reduces the amount of nitrogen fixed by 4.5% whereas an increase of 4% above optimum reduces nitrogen fixation by 5% (Skerman, *et al.*, 1988).

The persistence of legumes depends largely on its shade tolerance and its ultimate competition with the grasses and other plants for water and nutrients (Skerman, 1977).

However, legume persistence in mixed tropical grass-legume pastures is often poor. This is partly due to the strong competitiveness of the grass associated with its extensive root system, high N and P utilization efficiency and its tolerance to grazing Cadisch *et al.*, (1992) cited by Trannin *et al.*, (2000). Grasses and cereals are also known to possess a dual root system, which enables them to cope with varying conditions of water supply. Seminal roots with a low hydraulic conductivity provide slow access to water throughout the profile, while nodal or adventitious roots proliferate rapidly in the surface horizons following rewetting (Ong, *et al.* 1996).

2.6 Economics of introduction of legumes in natural pastures

The underlying question is whether introduction of legumes in natural pasture is economical. To answer this question let's consider the following case histories in Table 3.

Table 3: Comparison of animal weight gains in relation to pasture husbandry used

	Husbandry practiced	Live weight gains (kg/ha/year)
A	Burned, day pastures, traditional method of stock raising	10-15
B	Day pastures, burned once every 4 years; night pastures improved by sowing *Stylosanthes guianensis* and cutting with a rotary cutter. Fodder crops and distribution of silage (a Stylosanthes-sorghum mixture) during the last three months of the dry season at 10kg/head/day.	46
C	Unburned Control wholly treated mechanically to oversown *Stylosanthes guyanensis* at 2.5 kg/ha: distribution of silage during the last three months of dry season at 10kg/head/day. No fertilizers used	76

Source: Skerman (1977)

From the table above, system c is economically viable in the first year and from the second year returns a profit. The pasture composed of grass alone gave a per acre (0.405) return over costs of sh 130/- ($14.00), unfertilized grass/legume mixture sh. 275/- ($50.00) over fixed costs. This fertilized mixed grass/legume ley considerably increased the yield of the subsequent crops. (The figures given refer to costs in 1977).

2.7 Factors affecting nodulation and N-fixation

The factors fall into categories attributable to the bacteria and its host, nutritional and moisture aspects of the soil and the effects of climate (Crowder and Chedda, 1982). Calcium is important as a nutrient for functioning of the bacteria and the host plant. The bacteria (rhizobium) are Ca-sensitive but only require trace amounts. The host plant on the other hand requires a larger supply of Ca especially in nodule formation. Low soil pH is largely a function of Ca nutrition. In acid soils, calcium may not be available due to excess of Aluminum (Al) or Manganese (Mn) both of which antagonise Ca uptake. Phosphorus deficiency in many soils will severely limit both the formation of nodules and N-fixation, since it is required in the formation of enzyme nitrogenase. Cobalt is essential for growth of rhizobium. High levels of nitrates in the soil solution tend to inhibit nodulation.

2.8 Mineral nitrogen and legume growth

In mixed pastures, it has been always a problem to maintain the desired proportion of legumes to grass. Legumes grow just as well on mineral nitrogen as on nitrogen fixed from the air (Skerman, 1977).

Legume seedlings growing on a nitrogen-deficient soil usually exhibit a period of nitrogen starvation after the seed reserves are exhausted and before the nodules become fully effective. Addition of mineral nitrogen at this time can cause an increased legume growth that persists after the mineral nitrogen has been exhausted and plants become dependent on symbiotic fixation. Henzel (1970) studied this using 15 N isotope and showed that pasture legumes usually obtain less than their share of available nitrogen when grown in competition with grasses and other broad-leafed weeds. The fact that legume die out from mixed swards if they fail to nodulate is another evidence of their inability to compete for mineral nitrogen. It should also be noted that grasses in the tropics are quite nitrogen deficient. Addition of mineral nitrogen in mixed swards adds to their competitive advantage over legumes (Ong *et al*, 1996).

Additional response to mineral nitrogen application by legumes planted as pure stands is used as an indicator of the degree of fixation ability of the legume (Skerman, 1977).

2.9 Transfer of nitrogen from legumes to associated grasses

There are two main ways of nitrogen transfer from legumes to associated non-legumes in mixed pastures: transfer via the excreta of grazing livestock and underground transfer. The increase in N supply in mixed communities is thought to derive mainly from decomposition of above the ground litter. However, below the ground N transfer from legumes to the grass may also be substantial, particularly in systems with frequent defoliation and strong seasonality such as prolonged dry season with its associated root and nodule death. Below ground N transfer occurs from decaying roots, nodules, root exudates or direct transfer from the legume to the grass via mycorrizal hyphae (Ta and Faris, 1987b). Viera-Vargas *et al.* (1995) quoted by Trannin (2000) estimated that over 30% of N accumulated by tropical grasses could be derived from N_2 fixed by the associated legume. However, the more efficient transfer of fixed N_2 to the grass, the more competitive the grass becomes. Thus, adequate management is necessary to ensure legume persistence in mixed swards.

2.9.1 Transfer in excreta

Livestock excrete most of the nitrogen they ingest. Apparently the proportion that is ingested and excreted in urine rises with the concentration of nitrogen in the diet

(Skerman *et al*, 1988). Furthermore the nitrogen in the urine is more available for plant uptake than that in the feaces. Also nitrogen in feaces and urine is deposited on pasture unevenly especially by large grazing animals such as cattle. Even with high stocking rates, excreta affect nitrogen supply in only small fraction of the total grazing area at any point in time and a substantial portion of it is lost to the atmosphere.

2.9.2 Underground transfer

This term covers all other pathways of transfer, including those involving the legume tops (Henzel, 1970). Studies with tropical legumes have shown that there is a small proportion of transfer from young actively growing legumes. Relatively small rates can be transferred over periods of six months to two years (Skerman, 1977; Tranin *et al.*, 2000). The main transfer is caused by senescence, death and decomposition of plant material either from old tissues that died naturally or from tissues of any age killed by grazing, drought, disease etc. Whitney and Kanehiro (1967) found that in *Centrosema pubescens* and *Desmodium intortum* leaf fall is a more important source of transfer than leaching from live legume tops or release from nodules and roots following defoliation. Grazing pressure is another important method of underground transfer.

2.10 Digestibility of forages

This is an important measure of the nutritive value of forages and is defined as the difference in value between the feed eaten and materials voided by animals expressed as a percentage of feed eaten (McDonald *et al*, 1995; Javier, 1975; Morrison, 1984).

2.10.1 Measurements of digestibility of forages

These can be broadly categorized into two i.e. direct and indirect methods of estimating digestibility.

2.10.2 Direct methods:

These involve the use of live animals such as cattle, sheep and goats in feeding experiments (*in vivo*). The technique involves determination of forage DM or OM or chemical constituents eaten by animals confined to feeding/digestion stalls and respective amounts voided in faeces.

This can be represented by the equation:

$$\text{Digestibility } \% = \frac{C_{feed} - C_{faeces}}{C_{feed}} \times 100$$

Where:

C_{feed} and C_{faeces} refer to the amount of forage DM or constituent in forage eaten and faecal excretion respectively.

The method is expensive, laborious and time consuming and cannot be used in absence of animals. In addition, chemical composition can vary from day to day since forages have to be cut and fed daily during the experimental period. Special equipment are needed for collection of faeces and urine and animals are unable to express their selective eating habits (Crowder and Chheda, 1982).

2.10.3 Chemical Methods

2.10.3.1 *In vitro* method

The method attempts to approximate digestion in an artificial environment where rumen conditions are simulated in a test tube by incubating the dried forage sample with rumen fluid obtained from a fistulated animal, then buffering the fluid medium with an artificial solution of saliva and maintaining the temperature at the approximate rumen temperature of 39^0C during the 48 hour incubation period. The residue is then subjected to enzymatic digestion using enzyme pepsin for 48 hours (Tilley and Terry, 1963). The method may underestimate digestibility value if compared with *In vivo* method thus a regression equation can be used to correct this.

This is: *in vivo* digestibility = 0.99 x *in vitro* digestibility – 1.01 with SE =2.31 (Crowder and Chheda, 1982).

In vitro method is basically simple and quite efficient. It does not require expensive laboratory equipment and many samples can be analysed simultaneously.

However, a number of factors are known to affect the technique, which can cause errors. These include; variations in microbial populations, sample size, sample preparation and storage, particle size, pH of the medium during incubation and the procedures, duration of fermentation, dilution rate and the quality and source of rumen liquor. It has also been observed that, since a large number of samples are involved an error at one stage will influence results obtained in the subsequent stages. (Minson *et al* 1976; Chenyambuga, 1995). However, the method is considered to be the most accurate of all laboratory methods in prediction of *In vivo* digestibility and is recommended to be used for analysis of tropical forages (McDonald, *et al* 1995).

2.10.3.2 Nylon bag technique

The method uses nylon bags to determine digestibility of the feed. Six to ten grams of ground forage samples are placed in small bags made from nylon satin cloth or parachute nylon. Up to 48 of these bags are then tied to each of two circular steel weights and placed in the ventral sac of the rumen of a fistulated cow. The bags are removed after 48 hours, washed thoroughly under running water and dried in a forced air oven. The contents are weighed to determine dry matter loss for computation of digestibility. The rate of digestion of dry matter or chemical constituents can be determined by removing the bags at varying intervals (Crowder and Chheda, 1982). The method can be applied in situations where *In vitro* method may not be applicable.

2.10.4 Factors affecting digestibility of tropical forages

The nutritive value of a pasture is basically a function of the species, stage of growth, soil factors and climatic factors (Whiteman, 1980).

(i) Effect of climate on nutrient content of tropical forages.

Several workers have confirmed the influence of climate on nutrient content of tropical forages. Studies by Chenost and Sansourcy (1989) and Payne (1990) revealed that forages that grow under low rainfall have tremendously higher dry matter content than those grown in areas, which have abundant rainfall. McDonald *et al.*, (1995) stressed that forages in wet, humid and cloudy climate have relatively lower content of carbohydrates than those in dry and fine sunny areas. However, Payne (1990), Crowder and Chheda (1982) concluded that yields of green and dry matter, percentage crude protein, silica and ash are positively correlated with precipitation. Climatic factors such as temperature has an influence and affects chemical composition of tropical forages. High temperature result in rapid physiological maturation characterised by formation of high proportion of cell wall components (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). Thus Climate is the primary factor determining range forage production. This may vary widely with geographical area and season (Crowder and Chheda 1982).

(ii) Effects of species on the nutritive value of forage

Animals grazing tropical pastures generally have lower productivity than similar animals grazing temperate pastures (Mero, 1985). Many factors have been suggested to contribute to this lower productivity, but the most important is low feeding value of tropical pastures. High crude fibre, low crude protein, calcium and phosphorus contents have been reported in mature species (Osbourn, 1980).

(iii) Effect of age on nutritive value of tropical forages

As tropical forages mature, the proportion of potentially digestible components such as soluble carbohydrates, proteins and other cell contents tend to decline while the proportion of lignin, protected cellulose, hemicelluloses and other indigestible fractions such as cuticle and silica increase (Whiteman, 1980; Osbourn, 1980). However, the crude protein of grasses declines more rapidly than legumes.

2.11 Chemical composition of tropical forages

The nutritive value of forage refers to its chemical composition, digestibility and nature of digested products (Crowder and Chheda, 1982). Many elements in the plants are connected with body functions in animals.

The proximate analysis which is the most commonly used method fractions feeds into five fractions; crude protein (CP), fat or ether extract (EE), crude fibre (CF), ash and nitrogen-free extract (NFE).

In this procedure the following are the assumptions:

- Ether Extract recovers lipids and fats
- All nitrogen is protein which is 16%N
- CF recovers the least digestible fibrous and structural matter of the feed
- NFE represents highly digestible carbohydrates

All of these assumptions are not true because:

Ether Extract includes other substances such as waxes and pigments, which are of no nutritional significance. Plant tissues contain a variety of NPN, nitrates, nucleic acids and other insoluble fractions and NFE contains cumulative errors of all other determinations (Van Soest, 1994).

Factors affecting chemical composition

The main factors are; soil and climatic conditions, stage of growth and genotype.

Soil and climatic conditions

The physical and biological properties of the soil, rates at which nutrients are supplied and renewed in the rooting zone and fertilizer practices affect chemical composition. Most tropical soils are generally low in nitrogen. Deficiencies of other nutrients are also common depending on the extent of land utilization. In highly weathered tropical soils forages have greater tendency to absorb large quantities of silica, which significantly depresses digestibility of the herbage (Crowder and Chheda, 1982).

Fertilizer application alters yield and chemical composition in the forage depending whether its growth is limited by the nutrients derived from the fertilizer. Any nutrient below the critical level in the soil will affect forage yield. Addition of N fertilizer increases yield and CP content of the forage (Crowder and Chheda, 1982; Mohamed Saleem, 1972).

Stage of growth

As plants mature, the dry matter increases. This is reflected in increase in cell wall contents and decrease in cell contents. In most tropical grasses, CF and NFE continue to increase with age. Cell wall contents of herbage decrease with maturity. This does not mean that, elemental absorption has ceased. Rather, the rate of dry matter accumulation through photosynthetic activity is greater than the rate of mineral absorption. This causes dilution of mineral contents in proportion to increase in bulk and results in lower crude protein, P and K (Crowder and Chheda, 1982).

Genotype

Variations in chemical composition also arise as a result of genetic diversity of forage plants. Legumes are superior to grasses in feeding value. When different species of forage plants and different genotypes within a species are grown in common environment and under uniform management, estimations of their chemical composition and feeding value often reveal significant difference Reid *et al*, (1973); *Klock et al*., (1975) cited by Crowder and Chheda, (1982).

Sampling and processing

Herbage nutritive value estimations based on chemical composition are often unreliable, owing to difficulties in obtaining representative samples from the field. Furthermore, chemical analysis involve pretreatment of samples of which drying is the most important aspect. Uneven drying can bring about irreversible changes in chemical composition (Crowder and Chheda, 1982).

Effect of grazing or frequency of cutting on forage yield

When grasses or legumes are cut at frequent intervals throughout the season as on well-kept lawn, the total yield of dry matter is usually low than when they are allowed to grow to the usual stage (Morrison, 1984). This is because there is a smaller leaf surface exposed to the sunlight. Thus the production of carbohydrates through the action of sunlight on the chlorophyll of the leaves is decreased. Close grazing of pasture produces the same result.

Too frequent cutting or too close grazing of plants may also severely lessen their vigour because of depletion of reserve food in the roots. This not only reduces the yield but also cause the plants to die out (Morrison, 1984).

2.12 Influence of soil on pasture growth.

As Thomas (1940) remarked "best grasses grow on best soils". Soil plays an important role in pasture growth as all essential nutrients for growth are in the soil. The most important soil components, which influence soil physical and chemical properties, are nitrogen, phosphorus, potassium and pH.

Soil pH

The term pH is from the French *pouvoir hydrogene* or "hydrogen power". Soil reaction (pH) is an indication of the acidity or alkalinity of soil and is measured in pH units. The ranges of pH are from 0 to 14 with 7 being neutral point. From 7 to 0 the soil is increasing in acidity and from 7 to 14 the soil in increasing in alkalinity.

The pH provides clues about other soil properties. It greatly affects the solubility of minerals. Strongly acidic soils (pH 4-5) dissolve high even toxic concentrations of soluble aluminum and manganese (Miller and Donahue, 1995).

The soil pH can also influence plant growth by its effect on activity of beneficial microorganisms. Most nitrogen-fixing bacteria are not very active in strongly acidic soils (Miller and Donahue, 1995). Bacteria that decompose soil organic matter, releasing nitrogen and other nutrients for plant use are hindered by strong acidity.
The major effect of basic pH is to reduce the solubility of iron, zinc, copper and manganese.

Most soils become acidic because of leaching. Carbon dioxide (CO_2) dissolved in water, plus excreted $H^+(H_3O^+)$ from roots and some organic acids from humus decomposition, furnish H^+ in percolating water. As soil solution pH becomes acidic, aluminum hydroxides interact and some hydrated $Al(OH)_2^+$ ions form (Miller and Donahue, 1995). As percolating water moves these $Al(OH)_2^+$ and H_3O^+ ions through the soil, many adsorbed basic cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) are replaced by these acidic cations. Such leached soil becomes more acidic after some decades or centuries of leaching.

Nitrogen

Nitrogen is most often the limiting nutrient in plant growth (Miller and Donahue, 1995; Mestawet, 2000). It is a constituent of chlorophyll, plant proteins and nucleic acids. Nitrogen can be utilized by plants as ammonium cation or as the nitrate ion. Atmospheric dinitrogen (N_2) is made available by nitrogen fixation, which requires the action of specific microorganisms. Other soil nitrogen is made available by mineralization, which is the microbial decomposition of organic matter that releases nitrogen as ammonium ions. The ammonium ions are adsorbed on cation exchange sites (Miller and Donahue, 1995).

The nitrogen fixation by microorganisms is either symbiotic or nonsymbiotic. In symbiotic fixation, bacteria and actinomycetes cause the formation of root nodules in certain host plants and then inhabit those growths where they fix nitrogen.

In nonsymbiotic or free N_2 fixation, specific types of microorganisms exist independently in the soil and in water, convert N_2 into body tissue nitrogen forms and then release it for plant use when they die or are decomposed (Jensen, 1986).

Phosphorus

This is the second most important limiting nutrient. It is contained in plant cell nuclei and is part of energy storage and transfer chemicals in the plant. Soils have low total and low plant-available phosphate supplies because mineral phosphate forms are not readily soluble. Phosphorus used by the plant is taken up as the HPO_4^{2-} and $H_2PO_4^-$ anions (Coffman, 1978).

The total phosphorus in average arable soil is approximately 0.05% of which only infinite part is available to the plant at any one time (Miller and Donahue, 1995).

The original natural source of phosphorus is the mineral apatite, a calcium phosphate of low solubility with the typical formula $Ca_5(PO_4)_3$.

The soluble $H_2PO_4^-$ (orthophosphate) rapidly reacts in soil to form insoluble phosphates, a process loosely termed phosphate fixation (precipitation and fixation). In acid soils, the phosphate ions react with soluble iron and aluminum ions to form insoluble iron, aluminum and manganese hydroxides. In alkaline soils, low solubility calcium triphosphate is formed. Soluble phosphate ions also adsorb on solid calcium carbonate surfaces. Phosphorus is most available in near pH 6.5 (Miller and Donahue, 1995). There is no efficient mechanism in the soil to retain $H_2PO_4^-$ or HPO_4^{2-} ions in large quantities as exchangeable anions. Thus much of the phosphorus used by plants, other than that from applied phosphate fertilizers is believed to come from organic phosphates released by decomposition of organic matter (Khalid *et al*, 1979).

Soil Potassium

In the soil, K is released from weathering minerals and from cation exchange sites. Primary minerals containing K have very low solubility; so most K available to plants during growing season is supplied from the soil's exchangeable K reservoir (Miller and Donahue, 1995). K deficiencies are most common in leached soils (humid soils) where soluble and much of the exchangeable K has been leached out.

K chemicals are usually very soluble substances. K is not supplied from decomposing soil humus, except as an exchangeable ion on humus exchange sites.

Fresh plant residues contain 1-3% potassium common in plants, but that K is soluble and is leachable from the dead plant tissue. There is some competition for uptake among K, Ca, and Mg ions. The extent or exact reasons are not yet clear (Miller and Donahue, 1995). Some deficiency symptoms of K deficiency are bronzing of thick leathery leaves with no necroses, which snap when bent. The symptoms appear in younger leaves. Plants may differ greatly in the amounts and proportions of required nutrients. Each plant usually has a growth stage during which the need for one or more nutrients is much higher than during the rest of the plant's growth cycle. If nutrients are limiting during this critical peak-use period, yields will be reduced.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3. 1 Description of the study area

The study was conducted in Bukoba district of Kagera region in Tanzania. Kagera region is situated in the north-western part of Tanzania. It has a total area of 28,500 km^2 of which 20,000 km^2 is suitable for agriculture. The climate of the region is favourable for crop and animal production and over 80% of the total population are engaged in the two activities. In the past, livestock production in the region was marginalised. The reasons being diseases, inadequate delivery of livestock production inputs, poor nutrition, unreliable extension and veterinary services and poor forage growing in *rweya* (Omolo, *et al.*, 1999).

Livestock numbers in Kagera region has been increasing though at a slow rate. In 1926 cattle population in the then Lake province that included Kagera, Mwanza, Shinyanga and Mara regions was 1,211,259. It is estimated that Kagera region accounted for about 5% of this population (MoA, 1979). This was due to outbreak of Rinderpest in 1890-91, which killed about 90% of the cattle reducing the number from over 400,000 to less than 40,000 (van de Kopp, 1995). In the year 1984, the region had a total of 364,866 cattle, 343,317 goats, 54,117 sheep, 6,000 pigs and over 500,000 poultry (MoA, 1987).

Based on rainfall intensity and frequency, the region is divided into three rainfall zones; Bukoban high, medium and low rainfall respectively. The high rainfall zone includes areas around Lake Victoria with mean annual rainfall ranging from 2000-2500 mm, the medium rainfall areas have mean annual rainfall of 1500- 2000 mm and the low rainfall zone have an annual rainfall below 900 mm. No part of the region has been reported to have annual rainfall below 750mm (Baijukya and Folmer, 1999). The region receives a bimodal type of rainfall. Short rains start late August to December and the main rainfall starts in February to June of each year. Bukoba district can be divided according to dominant grass cover where there is *Eragrostis/Loudetia* zone or Bukoban system and *Themeda/Hyperrhenia* zone or Karagwe-Ankolean system.

High rainfall and very poor soil fertility characterize the *Eragrostis/Loudetia* zone (Lorkeers *et al* 1996).

The study was carried out in *Eragrostis/Loudetia* zone of Bukoba district at Maruku Agricultural Research and development Institute.

3.2 Pasture establishment

3.2.1 Site preparation and planting

Three *rweya* sites in the Agricultural Research and Development Institute (ARDI), Maruku were used for this experiment. Site selection was based on their fertility status. The sites were very poor *rweya* where *Eragrostis olivacea* was the dominant grass, medium *rweya* where *Hyperrhenia species* dominated and good (high) *rweya* where *Cynodon dactylon* and *Pennisetum clandestinum* (Kikuyu grass) were dominant grass species. These grasses were used as soil fertility indicators by the local community (*Lorkeers et al.*, 1995). Site preparation before oversowing involved clipping of the herbage to ground level. The leguminous plant species were sown in rows of 0.5 m apart in all plots. Three seeds were planted in each hole. Prior to planting, seeds were scarified by thoroughly rubbing them between the hands in order to break dormancy. The plot sizes were 6x $3.6m^2$ and were replicated three times per site giving a total number of thirty-three plots per site.

During planting Triple super phosphate fertilizer was applied in all sites and for all species. This was done to assist germination because the Bukoban soils are known to have very low available phosphorus and exchangeable potassium.

3.3 Agronomic data collection

Agronomic data collected were; germination percent and number of plants surviving in the first two months after oversowing. This was done in order to assess the adaptability of legumes in the Bukoban environment. The agronomic data were collected for all species in all sites. Data on germination were collected on a two-day interval for eighteen days after sowing. The number of seeds, which germinated in each hole for all species, was counted and recorded. After eighteen days, germination percentage was calculated basing on the number of seeds sown and those, which germinated. Data on number of plants available were taken based on germinated plants and were taken in each of the first two months of the study.

3.4 Legume species used

The five leguminous plant species used in the study were *Puereria phaseoloides, Macroptilium atropurpureum, Desmodium intortum, Centrosema pubescens* and *Clitoria ternatea* that are described in Appendix 1.

These species were selected basing on their nitrogen fixing ability, tolerance to heavy leaching and availability of seeds (Skerman *et al*, 1988).

3.5 Pasture sampling

3.5.1 Sample collection

From each plot a composite forage sample was taken by using a 0. 5m^2 quadrat. The samples were taken by clipping the area in the quadrat to ground level. Two samples were collected at different intervals from each plot. The first sample was collected on 25th March 2002 (seven months after oversowing) and the second sample was collected 15th May 2002 (seven weeks after first sampling). The interval was meant to assess the nutritive value of forages as affected by age. One control sample was collected before oversowing leguminous plant species while the second control samples were collected in the second harvest.

3.5.2 Sample preparation

In the oversown plots, no separation between legumes and grasses was done. Samples from each plot were weighed and put into paper bags. They were pre-dried in an oven at 60^0C to constant weight. This was done at ARDI Maruku Soil Science Laboratory.

The samples were transferred to the Department of Animal Science and Production (DASP) laboratory at Sokoine University of Agriculture (SUA) where they were ground using a hammer mill so as to pass through 2.5mm sieve. They were then bottled and kept ready for analysis.

3.5.3 Chemical analysis

Forage samples were analyzed for the following parameters: -

Dry Matter and Ash. These were analyzed according to (AOAC, 1990) procedures. CP was determined by Micro Kjedahl method. The cell wall components of the forages were analyzed according to Goering and Van Soest (1991) procedure, which includes neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL). In evaluating the digestibility of forages, the two-stage *In vitro* dry matter and organic digestibility determination developed by Tilley and Terry (1963) was used.

3.6 Soil sampling

3.6.1 Sample collection

Soil samples were collected using an auger at 0-30cm depth. Samples were collected in two intervals; one was taken before oversowing of the legumes and another eight months after oversowing the legumes. The samples were made into a composite immediately after collection. Sample preparation was done at ARDI Maruku Soil Science Laboratory. The aim of taking two samples was to compare changes in the soil nutrients as a result of oversowing leguminous plant species.

3.6.2 Soil chemical analysis

The samples were analyzed for the following parameters: Total nitrogen, which was determined using Kjedahl procedure as outlined by Bremner and Mulvaney (1982). Extractable phosphorus 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 1:2.5 soil-water or soil potassium chloride. Percent organic matter was obtained by determining the organic carbon by Walkey and Black wet digestion (potassium dichromate) method (Nelson and Sommers, 1982) and then by multiplying the value by the Van Bremmelem factor of 1.724.

3.7 Experimental design and statistical analysis

3.7.1 Experimental Design

The experimental design used was completely randomized block design. There were three blocks and six treatments including the control in each block. The blocks were replicated three times in each site. The treatments were as follows: T1= *Centrosema pubescens* plus natural pasture, T2= *Desmodium intortum* plus natural pasture, T3=*Macroptilium atropurpureum* plus natural pasture, T4= *Clitoria ternatea* plus natural pasture, T5= *Puereria phaseoloides* plus natural pasture and T6= control which consisted natural pasture alone (Appendix 2).

3.7.2 Statistical analysis

The data was analysed using the GLM procedure of SAS (SAS Inc, 1998) statistical package. Data on germination and percent survival were analysed using model one;

data on chemical composition and digestibility were analysed using model two while data on soil chemical properties were analysed using model three.

Model 1: This was used to analyse the percent number of leguminous plant species, which survived in the first two months after oversowing

$Y_{ijk} = \mu + L_i + S_j + (LS)_{ij} + e_{ijk}$

Where:

Y_{ijk} = k^{th} record of j^{th} species in i^{th} site

μ = Overall mean

L_i = Effect of i^{th} site (i = 1..3)

S_j = Effect of j^{th} species (j = 1..5)

$(LS)_{ij}$ = Site by species interaction

e_{ijk} = Random error

Model 2: This was used to analyse data on chemical composition and digestibility

$Y_{ijkl} = \mu + L_i + S_j + P_k + (LS)_{ij} + (SP)_{jk} + (LP)_{ik} + e_{ijkl}$

Where;

Y_{ijkl} = Record of l^{th} sample from k^{th} harvest from j^{th} species in i^{th} site

μ = Overall mean

L_i= effect of i^{th} site (i = 1..3)

S_j = Effect of j^{th} species (j =1..6)

P_k = Effect of k^{th} harvest (k = 1..2)

$(LS)_{ij}$ = Site by species interaction

$(SP)_{jk}$ = Species by harvest interaction

$(LP)_{ik}$ = Site by harvest interaction

e_{ijkl} = Random error

Model 3: This was used to analyse data soil chemical properties

$Y_{ijk} = \mu + L_i + S_j + (LS)_{ij} + e_{ijk}$

Where;

Y_{ijk} =Kth record from jth species in ith site

μ = Overall mean

L_i = Effect of ith site (i = 1..3)

S_j = Effect of jth species (j = 1..6)

$(LS)_{ij}$ =Site by species interaction

e_{ijk} =Random error

CHAPTER FOUR

4.0 RESULTS

4.1 General observations

Centrosema pubescens and *Puereria phaseoloides* established relatively well across all sites while *Macroptilium atropurpureum* and *Clitoria ternatea* disappeared from site three after two months. *Desmodium intortum* was able to survive well in site one and two. However, in site three it established relatively well when oversown but failed to survive in treatments where it was sown alone Table 5.

4.2 Agronomic data

4.2.1 Number of plants, which survived to the second month for oversown leguminous plant species

Table 4: Means for percent number of plants two months after oversowing leguminous plant species at ARDI Maruku, Bukoba

Sites	Species	Months	
		1	2
High	CEPU	60.21±3.61^{a}	57.14±2.54^{a}
	CLIT	58.98±3.61^{a}	54.49±2.54^{a}
	DESI	58.57±3.61^{a}	55.72±2.54^{a}
	PUPA	60.82±3.61^{a}	58.37±2.54^{a}
	MAAT	62.45±3.61^{a}	58.16±2.54^{a}
	Mean	60.21±1.18^{A}	56.78±1.18^{A}
Medium	CEPU	64.29±3.61^{a}	58.37±2.54^{ab}
	CLIT	47.96±3.61^{b}	35.51±2.54^{c}
	DESI	60.21±3.61^{a}	54.7±2.54^{ab}
	PUPA	63.68±3.61^{a}	60.21±2.54^{a}
	MAAT	59.19±3.61^{a}	52.45±2.54^{b}
	Mean	59.07±1.18^{A}	52.25±1.18^{B}
Poor	CEPU	45.92±3.61^{a}	31.84±2.54^{a}
	CLIT	21.23±3.61^{b}	0±2.54^{c}
	DESI	22.86±3.61^{b}	7.76±2.54^{b}
	PUPA	40.82±3.61^{a}	35.31±2.54^{a}
	MAAT	16.53±3.61^{b}	0±2.54^{c}
	Mean	29.47±1.18^{B}	14.98±1.18^{C}

SE= Standard Error

^{a,b,c} LSMeans within a column and within a site with different superscripts are significantly different ($P<0.05$)

$^{A, B, C}$ Overall site means between columns with different upper case superscript are significantly different ($P<0.05$)

CEPU: *Centrosema pubescens*

CLIT: *Clitoria ternatea*

DESI: *Desmodium intortum*

PUPA: *Puereria phaseoloides*

MAAT: *Macroptilium atropurpureum*

The results for the percent number of plants, which survived up to the second month after oversowing leguminous plant species, are presented in Table 4.

In site one, there was no significant difference ($P<0.05$) in the number of plants, which survived in the first and second months. In site two, during the first month, the number of plants, which survived, was significantly lower ($P<0.05$) in *C. ternatea* (47.96±3.61%). Other leguminous plant species were not significantly different. In the second month significantly lower ($P<0.05$) number of plants, which survived, was observed in *C. ternatea* (35.51±2.54%) while the highest value was observed in *P. phaseoloides* (60.21±2.54%). In site three, *C. pubescens* (45.92±3.61%) and *D. intortum* (16.53±3.61%) had higher number of plants that survived in the first month. Between sites, there was no significant difference in the mean survival in site one and two. However, significantly lower ($P<0.05$) mean survival (29.47±1.18 and 14±1.18%) were observed in site three in the first and second months respectively.

In site three the leguminous plant species had germination of 70.12%. However, *C. ternatea* and *M. atropurpureum* disappeared only after 2 months. The surviving legume species in this site had lower survival percentages 35.31±2.54%, 31.84±2.54% and 7.76±2.54% for *P. phaseoloides*, *C. pubescens* and *D. intortum* respectively. The leaves of dying plants started by turning yellow and eventually fell off which is a symptom of soil potassium deficiency.

There were site differences in the number of plants, which survived to the second month. Site one which was relatively more fertile had higher survival rate than the other two sites. These results implied that survival of legumes was influenced by soil fertility status especially nitrogen and available phosphorus.

Generally, the results show that, *M. atropurpureum* and *C. ternatea* did not perform well when oversown in the *rweya* soils of Bukoba and *P. phaseoloides*, *C. pubescens* and *D. intortum* performed better and may therefore be recommended for oversowing in the *rweya*.

4.3 Soil chemical properties

Table 5: Means for soil composition before and after oversowing leguminous species in natural pastures in ARDI Maruku, Bukoba

Sites	Treatments	Parameters				
		pH	OC(%)	N (%)	P(mg/kg)	Kcmol(+)/g
High	N+CEPU	5.41 ± 0.12^{b}	4.92 ± 0.16^{a}	0.39 ± 0.01^{a}	22.92 ± 6.31^{ab}	0.19 ± 0.04^{a}
	N+DESI	5.53 ± 0.12^{ab}	4.92 ± 0.16^{a}	0.38 ± 0.01^{a}	27.25 ± 6.31^{ab}	0.17 ± 0.04^{a}
	N+MAAT	5.55 ± 0.12^{ab}	5.02 ± 0.16^{a}	0.4 ± 0.01^{a}	41.16 ± 6.31^{a}	0.21 ± 0.04^{a}
	N+CLIT	5.58 ± 0.12^{ab}	5.12 ± 0.16^{a}	0.41 ± 0.01^{a}	25.67 ± 6.31^{ab}	0.2 ± 0.04^{a}
	N+PUPA	5.69 ± 0.12^{ab}	4.73 ± 0.16^{a}	0.42 ± 0.01^{a}	44.14 ± 6.31^{a}	0.22 ± 0.04^{a}
	Control	5.98 ± 0.12^{a}	3.49 ± 0.16^{b}	0.31 ± 0.01^{b}	14 ± 6.31^{b}	0.12 ± 0.04^{a}
	Mean	5.62 ± 0.08^{A}	4.7 ± 0.15^{B}	0.39 ± 0.02^{A}	29.2 ± 2.36^{A}	0.18 ± 0.01^{A}
Medium	N+CEPU	5.02 ± 0.26^{a}	5.25 ± 0.31^{a}	0.2 ± 0.02^{c}	7.29 ± 1.15^{b}	0.12 ± 0.01^{b}
	N+DESI	5.6 ± 0.26^{a}	6.14 ± 0.31^{a}	0.22 ± 0.02^{bc}	7.08 ± 1.15^{b}	0.11 ± 0.01^{b}
	N+MAAT	5.67 ± 0.26^{a}	5.46 ± 0.31^{a}	0.27 ± 0.02^{abc}	8.75 ± 1.15^{b}	0.13 ± 0.01^{b}
	N+CLIT	5.58 ± 0.26^{a}	5.8 ± 0.31^{a}	0.28 ± 0.02^{ab}	13.08 ± 1.15^{a}	0.1 ± 0.01^{b}
	N+PUPA	5.53 ± 0.26^{a}	5.83 ± 0.31^{a}	0.33 ± 0.02^{a}	8.92 ± 1.15^{b}	0.17 ± 0.01^{b}
	Control	5.76 ± 0.26^{a}	6.29 ± 0.31^{a}	0.11 ± 0.02^{d}	5.15 ± 1.15^{b}	0.1 ± 0.01^{b}
	Mean	5.53 ± 0.08^{A}	5.76 ± 0.15^{A}	0.24 ± 0.02^{B}	8.46 ± 2.36^{B}	0.12 ± 0.01^{B}
Poor	N+CEPU	5.64 ± 0.05^{a}	5.37 ± 0.24^{a}	0.21 ± 0.03^{a}	7.67 ± 0.75^{a}	0.07 ± 0^{a}
	N+DESI	5.61 ± 0.05^{a}	5.44 ± 0.24^{a}	0.22 ± 0.03^{a}	7.83 ± 0.75^{a}	0.06 ± 0^{ab}
	N+PUPA	5.53 ± 0.05^{a}	5.54 ± 0.24^{a}	0.25 ± 0.03^{a}	8.42 ± 0.75^{a}	0.1 ± 0^{c}
	Control	5.54 ± 0.05^{a}	5.44 ± 0.24^{a}	0.01 ± 0.03^{b}	7.17 ± 0.75^{a}	0.05 ± 0^{b}
	Mean	5.58 ± 0.1^{A}	5.45 ± 0.19^{A}	0.17 ± 0.03^{B}	7.76 ± 3.09^{B}	0.07 ± 0.01^{C}

^{a,b,c,d} LSMeans within a column and within a location with different superscripts are significantly different ($P<0.05$)

$^{A,\ B,C}$ Overall site means between columns with different upper case superscript are significantly different ($P<0.05$)

N + CEPU: Natural pasture oversown with *Centrosema pubescens*

N + CLIT: Natural pastures oversown with *Clitoria ternatea*

N + DESI: Natural pastures oversown with *Desmodium intortum*

N + PUPA: Natural pastures oversown with *Puereria phaseoloides*

N + MAAT: Natural pastures oversown with *Macroptilium atropurpureum*

The results of soil chemical properties before and after oversowing leguminous plant species are summarized in Table 5 and appendix 3.

In site one, soil pH was significantly high ($P<0.05$) in the control treatment (5.98±0.12) and it was low in the treatment oversown with *Centrosema pubescens* (5.41±0.12). Other treatments were not significantly different. Soil organic matter was not significantly different ($P<0.05$) between treatments. Total nitrogen did not differ significantly ($P<0.05$) between oversown treatments. However, it was significantly lower ($P<0.05$) in the control treatment (0.31±0.01%). Available phosphorus (P) was significantly higher ($P<0.05$) in treatments oversown with *P. phaseoloides* and *M. atropurpureum* (44. 14±6.31 and 41.16±6.31mg/kg respectively) while the lowest value was observed in the control treatment (14±6.31mg/kg). Other treatments were not significantly different. Exchangeable potassium (K) was not significantly different between treatments.

The soil results in site one implied that oversowing leguminous plant species in natural pastures improved soil chemical properties in terms of organic carbon (OC), total nitrogen and available phosphorus. For all treatments, total nitrogen changed from low to medium class which ranges between 0.21 to 0.50%. OC also remained in the very high class (>3.50%) throughout the experiment. Available P changed from medium to high class as a result of oversowing leguminous plant species in natural pastures.

In site two, there was no significant difference in pH and organic carbon between treatments. Total nitrogen was significantly higher ($P<0.05$) in the treatment oversown with *P. phaseoloides* (0.33±0.02%) while it was lowest in the control treatment (0.11±0.02%). Other treatments were also significantly different ($P<0.05$) in total nitrogen where the values observed were 0.2±0.02%, 0.22±0.02%, 0.27±0.02% and 0.28±0.02% for *C. pubescens*, *D. intortum*, *M. atropurpureum* and *C. ternatea* respectively. Available P was significantly higher ($P<0.05$) in the treatment oversown with *C. ternatea* (13.08±1.15mg/kg) while it was not significantly different between other treatments. Exchangeable K did not differ significantly between treatments.

The only parameters influenced by oversowing leguminous plant species in site two were total nitrogen which changed from low to medium status and available P. Significantly higher increases were observed in *P. phaseoloides* oversown treatment where available P and total nitrogen changed from medium to high status.

In site three, there were no significant differences between treatments in pH, OC and available P. Significant differences ($P<0.05$) were only observed in total nitrogen where the control treatments had the lowest (0.01±0.03%) total nitrogen. The oversown treatments were not significantly different. Exchangeable K was higher in the treatment oversown with *P. phaseoloides* (0.1±0Kcmol(+)/g).

The results showed that oversowing leguminous plant species in site three influenced total nitrogen from very low to medium status (0.1 to 0.21%) and exchangeable K which changed from very low to low status in *P. phaseoloides* oversown treatment (<0.13 to 0.13cmol (+)/kg) and had no effect on the other parameters.

Generally, oversowing leguminous plant species in all three sites improved some soil chemical properties. The changes were noted in total nitrogen, available P and K. Other parameters were not affected by oversowing. It was also observed that, *P. phaseoloides*, *C. ternatea* and *M. atropurpureum* were able to fix more nitrogen and available phosphorus than other treatments in all sites.

4.4 Dry matter yield

Table 6: Mean dry matter yield (kgDM/ha) of mixed and natural pasture during first and second harvests in ARDI Maruku, Bukoba

Sites	Treatments	Harvests (kgDM/ha)		Remarks
		1	2	
High	N+CEPU	$1101.69\pm188^{a,B}$	$2460.69\pm188^{a,A}$	**
	N+DESI	$954.91\pm188^{a,B}$	$2553.02\pm188^{a,A}$	***
	N+MAAT	$1291.08\pm188^{a,B}$	$2564.61\pm188^{a,A}$	*
	N+CLIT	$1077.71\pm188^{a,B}$	$1827.32\pm188^{ab,A}$	*
	N+PUPA	$1212.17\pm188^{a,B}$	$2013.92\pm188^{ab,A}$	*
	Control	$805.9\pm188^{a,B}$	$1167.99\pm188^{c,A}$	*
	Mean	$1073.92\pm58^{A,B}$	$2097.93\pm150^{A,B}$	***
Medium	N+CEPU	$1261.43\pm184^{a,A}$	$1578.01\pm184^{c,A}$	NS
	N+DESI	$1050.96\pm184^{a,B}$	$2205.59\pm184^{b,A}$	***
	N+MAAT	$1231.16\pm184^{a,B}$	$1892.72\pm184^{bc,A}$	*
	N+CLIT	$1072.35\pm184^{a,B}$	$2039.75\pm184^{bc,A}$	***
	N+PUPA	$1330.09\pm184^{a,B}$	$2436.35\pm184^{a,A}$	***
	Control	$904.12\pm184^{a,A}$	$1013.63\pm184^{d,A}$	NS
	Mean	$1141.68\pm58^{A,A}$	$1861\pm150^{A,B}$	***
Poor	N+CEPU	$971.49\pm162^{ab,B}$	$1361.07\pm162^{b,A}$	*
	N+DESI	$1270.56\pm162^{a,A}$	$1353.53\pm162^{b,A}$	*
	N+PUPA	$1384.36\pm162^{a,B}$	$2190.96\pm162^{a,A}$	**
	Control	$778.48\pm162^{b,B}$	$1577.15\pm162^{b,A}$	**
	Mean	$1101.21\pm71^{A,A}$	$1620.68\pm184^{A,B}$	**
	Remarks	NS	NS	

NS,*,**,*** = Non-Significant, Significant at ($P<0.05$), significant at ($P<0.01$) and significant at ($P<0.001$) respectively.

^{a,b,c,d} LSmeans within a column and within a site with different lowercase superscripts on the left of the slash are significantly different ($P<0.05$).

^{A,B}Harvest LSmeans with different uppercase superscript on the right of the slash are significantly different at probability level indicated in the remarks.

^{A,B,C} Overall site means between columns with different upper case superscript are significantly different ($P<0.05$)

Table 6 presents the results of mean dry matter yield of natural and mixed forages for the two harvests.

In site one during the first harvest, there were no significant differences ($P<0.05$) in DM yield between treatments. In the second harvest, treatments oversown with *M. atropurpureum, D. intortum* and *C. pubescens* had significantly higher ($P<0.05$) mean dry matter yield (2564.61±188, 2553.02±188 and 2460.69±188kgDM/ha respectively). The lowest value (1167.99±188kgDM/ha) was observed in the control treatment. Other treatments were not significantly different.

The results from this study in site one indicated that oversowing leguminous plant species increased dry matter yield in all oversown treatments. Most notable increases were observed in the second harvest where *M. atropurpureum*, *D. intortum* and *C. pubescens* oversown treatments outperformed the other treatments.

In site two, there was no significant difference in dry matter yield between treatments in the first harvest. In the second harvest, among the oversown treatments *P. phaseoloides* had the highest (2436.35±184kgDM/ha) mean dry matter yield followed by *D. intortum* (2205.59±184kgDM/ha) while significantly lower ($P<0.05$) values were observed in *C. pubescens* oversown treatment (1578.01±184kgDM/ha). However, within the site the control treatment had the lowest DM yield (1013.63±184kgDM/ha. Between harvests, significant differences ($P<0.001$) in dry matter yield were observed in *D. intortum*, *C. ternatea* and *P. phaseoloides* oversown treatments. *M. atropurpureum* had a significant difference (P<0.05) in dry matter yield between harvests.

In site three during the first harvest, *P. phaseoloides* and *D. intortum* oversown treatments had significantly higher (P<0.05) dry matter yield (1384.36±162 and 1270.56±162kgDM/ha respectively) while the control treatment had the lowest yield (778.48±162kgDM/ha). During the second harvest, *P. phaseoloides* oversown treatment had significantly higher (P<0.05) mean dry matter yield (2190.96±162kgDM/ha) while the other treatments were not significantly different. Between harvests, a significant difference (P<0.01) was observed in *P. phaseoloides* and the control.

The results from this study have shown that oversowing leguminous plant species into natural pastures has the potential to increase the dry matter yield of natural pastures. Among the leguminous plant species used in this study, most notable increases were observed in *C. pubescens*, *D. intortum* and *P. phaseoloides*.

4.5 Chemical composition of the natural and mixed forages during different harvests

4.5.1 Crude protein content of natural and mixed pasture in different harvests

Table 7: Mean crude protein (%) of natural and mixed forages during the first and second harvests for the samples from ARDI Maruku, Bukoba

Sites	Treatments	Harvests (%CP)		Remarks
		1	2	
High	N+CEPU	$11.28\pm0.64^{a,A}$	$9.14\pm0.64^{a,B}$	*
	N+DESI	$9.37\pm0.64^{bc,A}$	$8.84\pm0.64^{ab,A}$	NS
	N+MAAT	$9.43\pm0.64^{bc,A}$	$7.17\pm0.64^{b,B}$	*
	N+CLIT	$9.6\pm0.64^{ab,A}$	$7.37\pm0.64^{ab,B}$	*
	N+PUPA	$9.48\pm0.64^{abc,A}$	$8.29\pm0.64^{ab,A}$	NS
	Control	$7.74\pm0.64^{c,A}$	$7.82\pm0.64^{ab,A}$	NS
	Mean	$9.48\pm0.31^{A,A}$	$8.1\pm0.26^{A,B}$	***
Medium	N+CEPU	$8.17\pm0.43^{a,A}$	$7.76\pm0.43^{ab,B}$	*
	N+DESI	$7.51\pm0.43^{ab,B}$	$8.9\pm0.43^{a,A}$	*
	N+MAAT	$6.88\pm0.43^{b,A}$	$7.14\pm0.43^{b,A}$	NS
	N+CLIT	$7.64\pm0.43^{ab,A}$	$7.16\pm0.43^{b,A}$	NS
	N+PUPA	$7.66\pm0.43^{ab,B}$	$8.76\pm0.43^{a,A}$	*
	Control	$5.26\pm0.43^{c,A}$	$5.44\pm0.43^{c,A}$	NS
	Mean	$7.19\pm0.31^{B,A}$	$7.53\pm0.26^{A,A}$	NS
Poor	N+CEPU	$7.16\pm0.29^{a,A}$	$6.8\pm0.29^{a,A}$	NS
	N+DESI	$6.68\pm0.29^{a,A}$	$6.2\pm0.29^{b,A}$	NS
	N+PUPA	$7.49\pm0.29^{a,A}$	$7.11\pm0.29^{a,A}$	NS
	Control	$4.62\pm0.29^{b,B}$	$5.81\pm0.29^{b,A}$	**
	Mean	$6.4\pm0.38^{B,A}$	$6.57\pm0.32^{B,A}$	NS

SE = Standard Error

NS,*,**,*** = Non-Significant, Significant at ($P<0.05$), significant at ($P<0.01$) and significant at ($P<0.001$) respectively.

^{a,b,c,d} LSMeans within a column and within a site with different lowercase superscripts on the left of the slash are significantly different ($P<0.05$).

$^{A,\,B}$Harvest LSMeans with different uppercase superscript on the right of the slash are significantly different at probability level indicated in the remarks.

^{A,B,C} Overall site means between columns with different upper case superscript are significantly different ($P<0.05$)

The results of crude protein for natural and oversown treatments during different harvests are summarized in Table 7.

In site one during first the harvest, significantly higher ($P<0.05$) CP content was observed in *C. pubescens* oversown treatment (11.28±0.64%) and the lowest value was observed in the control treatment (7.74±0.64%).

The observed values for other treatments were also significantly different ($P<0.05$). These were 9.6±0.64, 9.48±0.64, 9.43±0.64 and 9.37±0.64% for *C. ternatea*, *P. phaseoloides*, *M. atropurpureum* and *D. intortum* oversown treatments respectively.

During the second harvest, *C. pubescens* oversown treatment had the highest CP content (9.14±0.64%) and the lowest value was observed in *M. atropurpureum* oversown treatment (7.17±0.64%). Other treatments were not significantly different.

Between harvests, there was a significant difference ($P<0.05$) in CP content of *C. pubescens*, *M. atropurpureum* and *C. ternatea* oversown treatments respectively. The mean site CP content was significantly different ($P<0.001$) between harvests. All treatments in site one had mean CP content above 6.5%, which is the minimum protein, required by ruminants to initiate rumen microbial activity.

In site two in the first harvest, the CP content of 8.17±0.43% observed in *C. pubescens* oversown treatment was significantly higher ($P<0.05$) compared to the other treatments. The lowest value was observed in the control treatment (5.26±0.43%). Among the oversown treatments, *M. atropurpureum* oversown treatment had the lowest CP content (6.88±0.43%). In the second harvest, *D. intortum* and *P. phaseoloides* oversown treatments had significantly higher ($P<0.05$) CP contents (8.9±0.43 and 8.76±0.43% respectively) while the lowest value was observed in the control treatment (5.44±0.43%). Between harvests, a significant difference ($P<0.05$) in CP content was observed in the treatment oversown with *D. intortum*.

In site three during the first harvest, there was no significant difference ($P<0.05$) in CP content among oversown treatments. However, the control treatment had the lowest CP content (4.62±0.29%). During the second harvest, significantly lower ($P<0.05$) values were observed in *D. intortum* oversown treatment and the control treatments (6.2±0.29 and 5.81±0.29% respectively). Other treatments were not significantly different. Between harvests a significant difference ($P<0.01$) was observed in CP content of the control treatment.

Generally the results showed that the CP content in site one was persistently higher in all treatments while lowest values were observed in site three. This could probably be due to the influence of soil fertility on forage composition. Site one had higher total nitrogen, extractable P and exchangeable K.

Another general observation on CP content between treatments in both harvests revealed the potential of oversowing leguminous plant species in improving the nutritive value of the pastures.

4.5.2 Neutral Detergent Fibre (NDF) of natural and mixed pasture samples of different harvests

Table 8: Mean NDF (%) of the natural and mixed forages during the first and second harvests at ARDI Maruku, Bukoba

Sites	Treatments	Harvests (%NDF)		Remarks
		1	2	
High	N+CEPU	$69.03\pm1.72^{b,A}$	$69.92\pm1.72^{b,A}$	NS
	N+DESI	$73.79\pm1.72^{a,A}$	$71.59\pm1.72^{b,A}$	NS
	N+MAAT	$72.79\pm1.72^{a, A}$	$74.53\pm1.72^{ab,A}$	NS
	N+CLIT	$69.46\pm1.72^{b,A}$	$74.35\pm1.72^{ab,A}$	NS
	N+PUPA	$69.73\pm1.72^{b,A}$	$69.6\pm1.72^{b,A}$	NS
	Control	$74.89\pm1.72^{a,A}$	$75.16\pm1.72^{a,A}$	NS
	Mean	$71.93\pm0.74^{A,A}$	$72.52\pm0.69^{B,A}$	NS
Medium	N+CEPU	$72.15\pm1.25^{c,B}$	$77.65\pm1.25^{ab,A}$	**
	N+DESI	$76.26\pm1.25^{ab,A}$	$74.4\pm1.25^{b,A}$	NS
	N+MAAT	$73.66\pm1.25^{bc,A}$	$75.11\pm1.25^{b,A}$	NS
	N+CLIT	$72.12\pm1.25^{c,B}$	$76.92\pm1.25^{ab,A}$	**
	N+PUPA	$71.63\pm1.25^{c,B}$	$76.73\pm1.25^{ab,A}$	**
	Control	$79.68\pm1.25^{a,A}$	$77.76\pm1.25^{a,A}$	NS
	Mean	$73.93\pm0.74^{A,B}$	$76.75\pm0.69^{A,A}$	**
Poor	N+CEPU	$71.42\pm1.26^{b,B}$	$76.86\pm1.26^{a,A}$	**
	N+DESI	$73.16\pm1.26^{b,B}$	$76.42\pm1.26^{a,A}$	**
	N+PUPA	$74.36\pm1.26^{ab,A}$	77.37 ± 1.26^{aA}	NS
	Control	$77.3\pm1.26^{a,A}$	$78.04\pm1.26^{a,A}$	NS
	Mean	$74.06\pm0.9^{A,B}$	$77.67\pm0.84^{A,A}$	**

NS,*,**,*** = Non-Significant, Significant at (P<0.05), significant at (P<0.01) and significant at (P<0.001) respectively.

^{a,b,c,d} LSMeans within a column and within a site with different lowercase superscripts on the left of the slash are significantly different (P<0.05).

$^{A, B}$Harvest LSMeans with different uppercase superscript on the right of the slash are significantly different at probability level indicated in the remarks.
^{A,B,C} Overall site means between columns with different upper case superscript are significantly different ($P<0.05$)

Table 8 presents a summary of the results on Neutral Detergent Fibre (NDF) content in all sites during the first and second harvests.

In site one during the first harvest, significantly ($P<0.05$) lower values were observed in the treatments oversown with *C. pubescens*, *C. ternatea* and *P. phaseoloides*, which had 69.03±1.72, 69.46±1.72 and 69.73±1.72% NDF respectively. The treatments oversown with *D. intortum*, *M. atropurpureum* and the control were observed to have significantly higher ($P<0.05$) NDF content. The observed values for this parameter were 74.89±1.72, 73.79±1.72 and 72.79±1.72% for the control, *D. intortum* and *M. atropurpureum* treatments respectively. During the second harvest, significantly lower ($P<0.05$) NDF values were observed in the *P. phaseoloides*, *C. pubescens* and *D. intortum* oversown treatments (69.6±1.72, 69.92±1.72 and 71.59±1.72% respectively). The control treatment had the highest value for this parameter (75.16±1.72%). There was no significant difference in NDF content between harvests in this site.

The results observed in this study showed that oversowing leguminous plant species into natural pastures reduced the NDF content of natural pastures, which is an important feature from nutritional point of view. It was also apparent that *C.*

pubescens and *P. phaseoloides* reduced the NDF content at higher rates than their counterparts in both harvests.

In site two in the first harvest, the control treatment had significantly higher (P<0.05) NDF content (79.93±1.25%). Lower values were observed in the treatments oversown with *P. phaseoloides* (71.63±1.25), *C. ternatea* (72.12±1.25) and *C. pubescens* (72.15±1.25%DM). During the second harvest, significantly higher (P<0.05) NDF value was observed in the control treatment (77.76±1.25%), lower values were observed in the treatments oversown with *D. intortum* (74.4±1.25%) and *M. atropurpureum* (75.11±1.25). Other treatments were not significantly different. Between the first and second harvests, there was a significant difference (P<0.01) in NDF values in the treatments oversown with *C. pubescens*, *C. ternatea* and *P. phaseoloides*.

The results also revealed that, oversowing reduced the NDF content of natural pastures. Among the oversown leguminous plant species, *C. pubescens*, *C. ternatea* and *P. phaseoloides* reduced NDF content of natural pastures at a relatively higher rate than their counterparts.

In site three during the first harvest, the control treatment had significantly (P<0.05) higher NDF content (77.3±1.26%) and the treatment oversown with *C. pubescens* had the lowest (71.42±1.26%) NDF content. During the second harvest, there was no significant difference (P<0.05) in NDF values between treatments.

Comparison of mean NDF content between sites in the first harvest showed that there was no significant difference between sites. However, during the second harvest, the mean NDF content observed in site one (72.52±0.69%) was significantly lower ($P<0.05$) than the other sites. This could probably be due to the differences in soil fertility between the sites, which was reflected by the type of dominant grasses in the sites.

Generally higher NDF values were observed in the second harvest than in the first. Of the oversown leguminous plant species, *C. pubescens*, *P. phaseoloides* and *C. ternatea* reduced the NDF content at higher a rate than their counterparts.

4.5.3 Acid Detergent Fibre (ADF) of the natural and mixed pasture samples in different harvests

Table 9: Mean ADF (%) of the natural and mixed forages during the first and second harvests at ARDI Maruku, Bukoba

Sites	Treatments	Harvests (%ADF)		Remarks
		1	2	
High	N+CEPU	$42.52\pm1.35^{a,A}$	$44.11\pm1.35^{b,A}$	NS
	N+DESI	$41.41\pm1.35^{a,A}$	$43.81\pm1.35^{b,A}$	NS
	N+MAAT	$43.56\pm1.35^{a,A}$	$42.97\pm1.35^{b,A}$	NS
	N+CLIT	$43.56\pm1.35^{a,A}$	$43.54\pm1.35^{b,A}$	NS
	N+PUPA	$41.24\pm1.35^{a,A}$	$40.78\pm1.35^{b,A}$	NS
	Control	$44.57\pm1.35^{a,A}$	$48.27\pm1.35^{a,A}$	NS
	Mean	$42.8\pm0.79^{B,A}$	$43.91\pm0.42^{B,A}$	NS
Medium	N+CEPU	$43.29\pm0.89^{b,B}$	$48.23\pm0.89^{a,A}$	***
	N+DESI	$43.92\pm0.89^{b,B}$	$47.43\pm0.89^{a,A}$	**
	N+MAAT	$46.88\pm0.89^{a,A}$	$45.73\pm0.89^{a,A}$	NS
	N+CLIT	$47.10\pm0.89^{a,A}$	$45.86\pm0.89^{a,A}$	NS
	N+PUPA	$37.22\pm0.89^{c,B}$	$45.71\pm0.89^{a,A}$	***
	Control	$47.67\pm0.89^{a,A}$	$49.23\pm0.89^{a,A}$	NS
	Mean	$44.59\pm0.79^{B,B}$	$46.77\pm0.42,A^{A}$	*
Poor	N+CEPU	$46.62\pm0.61^{a,A}$	$48.25\pm0.61^{ab,A}$	NS
	N+DESI	$46.29\pm0.61^{ab,B}$	$48.85\pm0.61^{ab,A}$	**
	N+PUPA	$44.73\pm0.61^{b,A}$	$46.4\pm0.61^{b,A}$	NS
	Control	$47.71\pm0.61^{a,B}$	$50\pm0.61^{a,A}$	*
	Mean	$46.34\pm0.96^{A,B}$	$48.37\pm0.51^{A,A}$	**

NS,*,**,*** = Non-Significant, Significant at ($P<0.05$), significant at ($P<0.01$) and significant at ($P<0.001$) respectively.

^{a,b,c,d} LSMeans within a column and within a site with different lowercase superscripts on the left of the slash are significantly different ($P<0.05$).

^{A,B}Harvest LSMeans with different uppercase superscript on the right of the slash are significantly different at probability level indicated in the remarks.

^{A,B,C} Overall site means between columns with different upper case superscript are significantly different ($P<0.05$)

Table 9 and Appendix 3 summarize results on Acid Detergent Fibre (ADF) in the first and second harvests in all sites.

In site one during the first harvest, there was no significant difference ($P<0.05$) in ADF values between treatments. During the second harvest, significantly higher ($P<0.05$) ADF value was observed in the control treatment (48.27±1.35%) while other treatments were not significantly different.

It may be remarked that during the first harvest, the forages were still young hence the cell wall content of the plants was low but as they aged, the cell wall content of the plants increased hence higher ADF.

In site two during the first harvest, significantly higher ($P<0.05$) ADF content was observed in the control and the treatments oversown with *C. ternatea* and *M. atropurpureum*, which had 49.23±0.89, 47.1±0.89 and 46.88±0.89% ADF respectively. During the second harvest, there was no significant difference ($P<0.05$) in ADF content between treatments. Between the first and the second harvests, significant differences ($P<0.001$) in ADF values were observed in the treatments oversown with *C. pubescens* and *P. phaseoloides* and a significant difference ($P<0.01$) was also observed for the treatment oversown with *D. intortum*. Other treatments were not significantly different in the second and first harvests.

It was evident from this study that, higher ADF content were observed in the second harvest for all treatments. This could be attributed to the influence of age on the cell wall components of the plants.

In site three during the first harvest, lowest ADF content (44.73±0.61%) was observed in the treatment oversown with *P. phaseoloides* while the control and the treatment oversown with *C. pubescens* had higher ADF content (47.71±0.61 and 46.62±0.61% respectively). During the second harvest, significantly higher ($P<0.05$) ADF content was observed in the control treatment (50±0.61%) while the lowest value was observed in the treatment oversown with *P. phaseoloides* (46.4±0.61%). Other treatments were not significantly different.

Mean ADF was significantly lower in site one (42.8±079%DM) followed by site two (44.59±0.79%) while a significantly higher ($P<0.05$) value was observed in site three (46.34±0.96%).

The higher ADF content observed in site three could be due to poorer grasses, which dominated the site. It was also evident that, leguminous plant species had little influence on ADF content in the first harvest. However during the second harvest a significant influence of legumes on ADF content was observed in treatments oversown with *P. phaseoloides* and *D. intortum*. Other legumes did not influence this parameter.

4.5.4 Acid Detergent Lignin (ADL) of the natural and mixed pasture samples in different harvests

Table 10: Mean ADL (%) of the natural and mixed forages during first and second harvests at ARDI Maruku, Bukoba.

Sites	Treatments	Harvests (%ADL)		Remarks
		1	2	
High	N+CEPU	$6.70\pm0.59^{ab,B}$	$11.05\pm0.59^{b,A}$	***
	N+DESI	$5.06\pm0.59b^{c,B}$	$10.92\pm0.59^{b,A}$	***
	N+MAAT	$7.78\pm0.59^{a,B}$	$9.92\pm0.59^{b,A}$	***
	N+CLIT	$4.54\pm0.59^{c,B}$	$10.92\pm0.59^{b,A}$	***
	N+PUPA	$3.69\pm0.59^{c,B}$	$10.19\pm0.59^{b,A}$	***
	Control	$4.54\pm0.59^{c,B}$	$13.46\pm0.59^{a,A}$	***
	Mean	$5.41\pm0.28^{B,B}$	$10.93\pm0.52^{A,A}$	***
Medium	N+CEPU	$7.97\pm0.45^{b,B}$	$11.13\pm0.45^{ab,A}$	***
	N+DESI	$8.83\pm0.45^{ab,B}$	$11.17\pm0.45^{ab,A}$	***
	N+MAAT	$7.61\pm0.45^{b,B}$	$11.29\pm0.45^{ab,A}$	***
	N+CLIT	$8.18\pm0.45^{b,B}$	$10.86\pm0.45^{ab,A}$	***
	N+PUPA	$7.46\pm0.45^{b,B}$	$10.54\pm0.45^{b,A}$	***
	Control	$9.68\pm0.45^{a,B}$	$12.01\pm0.45^{a,A}$	***
	Mean	$8.24\pm0.28^{A,B}$	$11.17\pm0.52^{A,A}$	***
Poor	N+CEPU	$8.31\pm0.36^{ab,B}$	$10.67\pm0.36^{b,A}$	***
	N+DESI	$8.47\pm0.36^{ab,B}$	$10\pm0.36^{b,A}$	**
	N+PUPA	$7.98\pm0.36^{b,B}$	$10.88\pm0.36^{b,A}$	***
	Control	$10.26\pm0.36^{a,B}$	$18.59\pm0.36^{a,A}$	***
	Mean	$8.76\pm0.34^{A,B}$	$12.54\pm0.63^{A,A}$	**

NS,*,**,*** = Non-Significant, Significant at ($P<0.05$), significant at ($P<0.01$) and significant at ($P<0.001$) respectively.

^{a,b,c,d} LSMeans within a column and within a site with different lowercase superscripts on the left of the slash are significantly different ($P<0.05$).

$^{A,\ B}$Harvest LSMeans with different uppercase superscript on the right of the slash are significantly different at probability level indicated in the remarks.

^{A,B,C} Overall site means between columns with different upper case superscript are significantly different ($P<0.05$)

Table 10 summarizes the results of mean ADL for the natural and mixed treatments during the first and second harvests.

In site one during the first harvest, Acid Detergent Lignin (ADL) was significantly higher (P<0.05) in the treatment oversown with *M. atropurpureum* (7.8±0.59%) and lower ADL content was observed in the treatments oversown with *P. phaseoloides* (3.6±0.59%), *C. ternatea* (4.54±0.59%), *D. intortum* (5.06±0.59%) and the control treatment (4.54±0.59%). During the second harvest, significantly higher ADL content was observed in the control treatment (13.46±0.59%) while other treatments were not significantly different.

A highly significant difference (P<0.001) was observed in ADL content between the first and second harvests where all treatments in the second harvest had higher values than the first harvest. This could be attributed to the high rainfall, which was experienced during the second harvest.

It might be remarked that, oversowing leguminous plant species in natural pastures did not influence ADL content.

In site two in the first harvest, the control treatment had significantly (P<0.05) higher ADL content (9.68±0.45%), the other treatments were not significantly different. During the second harvest, significantly higher (P<0.05) ADL content was observed in the control treatment (12.01±0.52%) and the lowest value was observed in the treatment oversown with *P. phaseoloides* (10.54±0.45%). Other treatments were not significantly different.

In site three during the first harvest, significantly higher (P<0.05) values were observed in the control treatment, which had 10.26±0.36% ADL and the natural pasture oversown with *P. phaseoloides* had the lowest value (7.98±0.36%). During the second harvest, the control treatment had the highest ADL content (18.59±0.36%) and the other treatments were not significantly different.

From the results obtained in this study, it was clear that, oversowing leguminous plant species in natural pastures did not influence ADL content.

4.5.5 Ash content of the natural and mixed pasture samples in different harvests

Table 11: Ash content (%) of the natural and mixed forages during first and second harvests at ARDI Maruku, Bukoba

Sites	Treatments	Harvests (%Ash)		Remarks
		1	2	
High	N+CEPU	$8.92\pm0.8^{a,A}$	$8.87\pm0.8^{a,A}$	NS
	N+DESI	$5.48\pm0.8^{b,A}$	$6.57\pm0.8^{b,A}$	NS
	N+MAAT	$7.11\pm0.8^{ab,A}$	$7.84\pm0.8^{ab,A}$	NS
	N+CLIT	$8.49\pm0.8^{a,A}$	$6.84\pm0.8^{ab,A}$	NS
	N+PUPA	$7.49\pm0.8^{ab,A}$	$9.41\pm0.8^{a,A}$	NS
	Control	$6.86\pm0.8a^{b,A}$	$8.04\pm0.8^{ab,A}$	NS
	Mean	$7.39\pm0.33^{A,A}$	$7.93\pm0.41^{A,A}$	NS
Medium	N+CEPU	$6.24\pm0.82^{a,A}$	$7.24\pm0.82^{b,A}$	NS
	N+DESI	$7.69\pm0.82^{a,A}$	$6.64\pm0.82^{b,A}$	NS
	N+MAAT	$7\pm0.82^{a,A}$	$6.66\pm0.82^{b,A}$	NS
	N+CLIT	$7.85\pm0.82^{a,A}$	$5.41\pm0.82^{b,A}$	NS
	N+PUPA	$6.5\pm0.82^{a,A}$	$5.98\pm0.82^{b,A}$	NS
	Control	$5.52\pm0.82^{a,B}$	$10.08\pm0.82^{a,A}$	***
	Mean	$6.8\pm0.33^{AB,A}$	$7\pm0.41^{AB,A}$	NS
Poor	N+CEPU	$5.74\pm0.52^{a,B}$	$8.24\pm0.52^{a,A}$	**
	N+DESI	$5.8\pm0.52^{a,A}$	$6.16\pm0.52^{b,A}$	NS
	N+PUPA	$5.87\pm0.52^{a,A}$	$5.68\pm0.52^{b,A}$	NS
	Control	$6.72\pm0.52^{a,A}$	$4.69\pm0.52^{b,B}$	**
	Mean	$6.03\pm0.4^{B,A}$	$6.19\pm0.5^{B,A}$	NS

NS,*,**,*** = Non-Significant, Significant at ($P<0.05$), significant at ($P<0.01$) and significant at ($P<0.001$) respectively.

^{a,b,c,d} LSMeans within a column and within a site with different lowercase superscripts on the left of the slash are significantly different ($P<0.05$).

$^{A,\ B}$Harvest LSMeans with different uppercase superscript on the right of the slash are significantly different at probability level indicated in the remarks.

^{A,B,C} Overall site means between columns with different upper case superscript are significantly different ($P<0.05$)

Table 11 summarizes results for mean ash content for the natural and oversown treatments in both the second and first harvests.

In site one during the first harvest, ash content was significantly higher (P<0.05) in treatments oversown with *C. pubescens* and *C. ternatea* with 8.92±0.8 and 8.49±0.8% respectively. Lower ash contents were observed in treatments oversown with *D. intortum* (5.48±0.8%) and the control (6.86±0.8%). During the second harvest, *P. phaseoloides* and *C. pubescens* oversown treatments had significantly higher (P<0.05) ash content (9.41±0.8 and 8.87±0.8% respectively) and lower ash content (6.57±0.8%) was observed in *D. intortum* oversown treatment.

In site two and three, there was no significant difference (P<0.05) in ash content between treatments during the first and the second harvests. These results revealed that oversowing leguminous plants in natural pastures did not influence ash content between treatments and harvests.

Based on the results on chemical composition observed in this study it can be concluded that oversowing leguminous plant species in natural pastures influenced the nutritive value of forages. Most significant improvements were observed in increased CP content and reduction of cell wall components of the forages especially in terms of NDF and ADF. It was also observed that oversowing did not influence ADL and ash contents. Another important observation noted from this study was that there were species differences in influencing the nutritive value of forages where *P. phaseoloides*, *C. pubescens* and *D. intortum* had a significant influence on the above mentioned parameters. It might also be concluded that soil fertility status influenced chemical composition of forages. Site one, which had higher total nitrogen and available P, had forages with higher nutritive value while site three, which had poor soil fertility had forages with poor nutritive value.

4.6 Digestibility

4.6.1 *In vitro* dry and organic matter digestibility for the natural and mixed pasture samples during the first and second harvests

Table 12: Mean *In vitro* dry matter digestibility (%) for the natural and mixed pastures during the first and second harvests at ARDI Maruku

Sites	Treatments	Harvests (IVDMD)		Remarks
		1	2	
High	N +CEPU	$37.95\pm1.81^{a,A}$	$33.23\pm3.13^{ab,A}$	NS
	N +DESI	$40.08\pm1.81^{a,A}$	$35.98\pm1.81^{ab,A}$	NS
	N+MAAT	$38.2\pm1.81^{a,A}$	$36.04\pm1.81^{ab,A}$	NS
	N +CLIT	$39.82\pm1.81^{a,A}$	$38.74\pm1.81^{a,A}$	NS
	N +PUPA	$38.22\pm1.81^{a,A}$	$38.47\pm1.81^{a,A}$	NS
	Control	$37.27\pm1.81^{a,A}$	$32.52\pm1.81^{b,A}$	NS
	Mean	$38.5\pm0.96^{A,A}$	$36.16\pm1.33^{A,B}$	*
Medium	N +CEPU	$38.77\pm3.11^{ab,A}$	$36.61\pm3.11^{a,A}$	NS
	N +DESI	$38.42\pm3.11^{ab,A}$	$37\pm3.11^{a,A}$	NS
	N+MAAT	$41.59\pm3.11^{a,A}$	$30\pm3.11^{a,B}$	*
	N +CLIT	$38.11\pm3.11^{ab,A}$	$36.08\pm3.11^{a,A}$	NS
	N +PUPA	$38.98\pm3.11^{ab,A}$	$35.4\pm3.11^{a,A}$	NS
	Control	$31.21\pm3.11^{b,A}$	$30.8\pm3.11^{a,A}$	NS
	Mean	$38.24\pm1.29^{A,A}$	$34.32\pm0.93^{B,A}$	NS
Poor	N +CEPU	$35.79\pm2.13^{ab,A}$	$33.46\pm2.13^{ab,A}$	NS
	N +DESI	$41.19\pm2.13^{a,A}$	$37.89\pm2.13^{a,A}$	NS
	N +PUPA	$34.44\pm2.13^{b,A}$	$33.65\pm2.13^{ab,A}$	NS
	Control	$28.54\pm2.13^{c,A}$	$27.78\pm2.13^{b,A}$	NS
	Mean	$34.8\pm1.54^{A,A}$	$33.39\pm1.14^{B,A}$	NS

NS,*,**,*** = Non-Significant, Significant at ($P<0.05$), significant at ($P<0.01$) and significant at ($P<0.001$) respectively.

^{a,b,c,d} LSMeans within a column and within a site with different lowercase superscripts on the left of the slash are significantly different ($P<0.05$).

^{A,B}Harvest LSMeans with different uppercase superscript on the right of the slash are significantly different at probability level indicated in the remarks.

^{A,B,C} Overall site means between columns with different upper case superscript are significantly different ($P<0.05$).

The results of *In vitro* dry matter digestibility (INVDMD) of the natural and mixed pasture samples during the first and second harvests are presented in Table 12.

In site one during the first harvest, there was no significant difference in IVDMD between treatments. During the second harvest, the observed values of 38.74±1.81% and 38.47±1.81% respectively observed in *C. ternatea* and *P. phaseoloides* oversown treatments were significantly higher ($P<0.05$) than the other treatments. The lowest value (32.52±1.81%) was observed in the control treatment. Based on the results it was apparent that, oversowing leguminous plant species improved the digestibility of natural forages.

In site two in the first harvest, *M. atropurpureum* oversown treatment had significantly higher ($P<0.05$) IVDMD (41.59±3.11%) and the control treatment had the lowest value (31.21±3.11%). There was no significant difference between other treatments. In the second harvest, there was no significant difference between treatments.

In site three in the first harvest, *D. intortum* oversown treatment had significantly ($P<0.05$) higher IVDMD than the other treatments while the control treatment had the lowest value. Other treatments were also significantly different. The observed values were 41.19±2.13, 35.79±2.13, 34.44±2.13, and 27.78±2.13% for *D. intortum*, *C. pubescens*, *P. phaseoloides* and the control treatment respectively. In the second harvest, *D. intortum* had higher IVDMD (37.89±2.13%) while the control treatment had lower INVDMD (27.78±2.13%). Other treatments did not differ significantly.

These results show that, oversowing leguminous plant species in natural pastures increased *In vitro* dry matter digestibility of natural pastures. It was also observed that, lower IVDMD values were observed in the second harvest, which could be attributed to the effect of age on forages. As plants mature they tend to increase the cell wall fraction, which tend to negatively influence their digestibility. The influence of soil fertility status on digestibility was clearly shown from the results obtained in this study during the second harvest. Site one, which was relatively fertile, had higher IVDMD than the other sites.

4.6.2 *In vitro* organic matter digestibility for the natural and mixed pasture samples during first and second harvests

Table 13: Mean *In vitro* organic matter digestibility (%) for the natural and mixed pasture during first and second harvests at ARDI Maruku, Bukoba

Sites	Treatments	Harvests (IVOMD)		Remarks
		1	2	
High	N +CEPU	$51.48\pm1.66^{a,A}$	$47.4\pm1.66^{a,A}$	NS
	N +DESI	$53.91\pm1.66^{a,A}$	$50.06\pm1.66^{a,A}$	NS
	N+MAAT	$52.27\pm1.66^{a,A}$	$50\pm1.66^{a,A}$	NS
	N +CLIT	$53.58\pm1.66^{a,A}$	$52.49\pm1.6,A6^{a}$	NS
	N +PUPA	$53.61\pm1.66^{a,A}$	$51.97\pm1.66^{a,A}$	NS
	Control	$47.46\pm1.66^{a,A}$	$46.12\pm1.66^{b,A}$	NS
	Mean	$52.05\pm0.95^{A,A}$	$49.67\pm1.39^{AB,A}$	NS
Medium	N +CEPU	$53.11\pm3.14^{a,A}$	$50.66\pm3.14^{a,A}$	NS
	N +DESI	$53.32\pm3.14^{a,A}$	$51.86\pm3.14^{a,A}$	NS
	N+MAAT	$55.98\pm3.14^{a,A}$	$49.88\pm3.14^{a,A}$	NS
	N +CLIT	$51.96\pm3.14^{a,A}$	$50.09\pm3.14^{a,A}$	NS
	N +PUPA	$55.56\pm3.14^{a,A}$	$49.31\pm3.14^{a,A}$	NS
	Control	$46.96\pm3.14^{a,A}$	$44.39\pm3.14^{a,A}$	NS
	Mean	$53.16\pm0.95^{A,A}$	$49.33\pm1.35^{A,A}$	NS
Poor	N +CEPU	$49.93\pm2.49^{a,A}$	$47.62\pm2.49^{b,A}$	NS
	N +DESI	$55.09\pm2.49^{a,A}$	$51.4\pm2.49^{a,A}$	NS
	N +PUPA	$51.07\pm2.49^{a,A}$	$47.17\pm2.49^{b,A}$	NS
	Control	$42.45\pm2.49^{b,A}$	$41.71\pm2.49^{c,A}$	NS
	Mean	$49.61\pm1.14^{A,a}$	$46.98\pm1.61^{B,A}$	NS

NS,*,**,*** = Non-Significant, Significant at ($P<0.05$), significant at ($P<0.01$) and significant at ($P<0.001$) respectively.

^{a,b,c,d} LSMeans within a column and within a site with different lowercase superscripts on the left of the slash are significantly different ($P<0.05$).

$^{A,\,B}$Harvest LSMeans with different uppercase superscript on the right of the slash are significantly different at probability level indicated in the remarks.

^{A,B,C} Overall site means between columns with different upper case superscript are significantly different ($P<0.05$).

The results of *In vitro* organic matter digestibility (IVOMD) for mixed and natural pastures during the first and second harvests are presented in Table 13.

In site one in the first harvest, there was no significant difference ($P<0.05$) between treatments. In the second harvest, the lowest IVOMD (46.12±1.66%) value was observed in the control treatment. There was no significant ($P<0.05$) differences between other oversown treatments.These results implied that, oversowing leguminous plant species influenced IVOMD of the natural pastures.

In site two during the first and second harvests, there was no significant difference in IVOMD between treatments.

In site three during the first harvest, the lowest IVOMD (42.45±2.49%) was observed in the control treatment while the other treatments did not differ significantly ($P<0.05$). In the second harvest, *D. intortum* oversown treatment had the highest IVOMD (51.4±2.49%) and the control treatment had the lowest IVOMD (41.71±2.49%).

There was a general decline in digestibility values in the second harvest. Age could be sited as the cause of this trend due to increased lignification as plants mature hence low digestibility. However, the results revealed that, oversowing leguminous plant species into natural pastures increased their digestibility. It was also observed that, site three had the lowest mean IVOMD (46.98±1.61%) compared to the other sites. The reason for this could possibly be due to lower soil fertility especially soil nitrogen. Site one had total nitrogen of 0.39±0.02% and site three had total nitrogen of 0.17±0.03%.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Soil physical and chemical properties

Several studies have shown that apart from improving the nutritive value of natural pasture, oversowing legumes into natural pasture improves soil fertility (Crowder and Chheda, 1982; Mero, 1985; Skerman, 1977; CIAT, 1992). The results from this study have proved that, leguminous plant species have the potential to improve soil chemical properties. Most observable improvements were clearly seen in total nitrogen, available phosphorus, and exchangeable potassium. The observed values for soil pH ranged between 5.41±0.12 to 5.98±0.12, Organic Carbon ranged between 4.73±0.16 to 6.29±0.31%, total nitrogen ranged between 0.01±0.03 to 0.42±0.01%, available phosphorus ranged between 7.08±1.15 to 44.14±6.31mg/kg and exchangeable potassium ranged between 0.05±0 to 0.22±0.04cmol(+)/g.

Soil pH was not affected by oversowing legumes in natural pastures. This is because most tropical legumes are able to grow in a wide range of soils including acidic soils (t'Mannetje, 1980). Soil pH remained in strongly acidic condition throughout the study (Baize, 1993;EUROCONSULT, 1989; Landon, 1991).

Oversowing leguminous plant species in natural pastures did not influence the soil organic carbon. However, it has been revealed that Bukoban soils are characterized by high organic carbon (Touber and Kanani, 1994). This is mainly due to high organic matter produced by bulk grasses growing in *rweya* as a result of high rainfall throughout the year (Milne, 1938; Baijukya and Folmer, 1999). It has also been observed that, high organic matter in Bukoban soils does not necessarily reflect good soil fertility. This is because the bulk of grasses growing in *rweya* are very poor in terms of soil nutrients and are inert, thus do not contribute much to soil fertility (Touber and Kanani, 1994). In addition, Mestawet (2000) found an increase of only 2% in organic carbon after seven years of legume inclusion in Shinyanga. This possibly suggests that, an adequate amount of time is required before realizing an increase in organic carbon of the soil.

In tropical soils nitrogen has been cited as the most limiting element limiting plant growth (Miller and Donahue 1995; Crowder and Chheda, 1982; Mestawet, 2000). The use of legumes has been cited as one of the low input approaches of improving total soil nitrogen due to the ability of legumes to fix atmospheric nitrogen into usable component (Crowder and Chheda, 1982; Giller, 2001). In site one of this study, oversowing legumes in natural pasture increased the nitrogen content from 0.3 to an average of 0.4%. This was an increase of 25%. In site two, total nitrogen increased from 0.12 to 0.26%. This was an increase of 14%. In site three, oversowing legumes increased soil nitrogen from 0.1 to an average of 0.22%, which was an increment of 12%. On average oversowing legumes in *rweya* increased nitrogen by 17% in this study. Generally legumes increased total nitrogen from low to medium status in site one and two (Baize, 1993;EUROCONSULT, 1989; Landon, 1991). Other studies have also shown that legumes contribute to soil nitrogen in varying amounts. Mestawet, (2000) found that legumes increased soil nitrogen from 0.2 to 0.26 in Shinyanga, which was an increase of 26.08 percent. Wilson *et al* (1982) cited by Abubeker (1997) also found an increment of soil nitrogen of 34.27 percent as a result of inclusion of legumes in the soil. The findings of this study are not different from the other results. It was also observed that on average, *P. phaseoloides* fixed more nitrogen and available phosphorus than the other legumes in all sites (Table 6). This is in agreement with the findings of Schofield (1945) quoted by Skerman *et al* (1988) who found puero to be a better contributor of nitrogen than stylo, calopo and centro. It was observed that in site one, the average amount of soil nitrogen and P fixed was high than in other sites. Hauck, (1984) observed that the amount of nitrogen fixed by legumes depends on the amount of soil N available before legumes are introduced and type of legumes used. Site one was formerly a dairy unit at the institute hence it was more fertile than the other sites.

The effect of legumes on available phosphorus was high in site one and two while it was non-significant in site three. Generally Bukoban soils have higher P levels usually ranging between 4-8% (Lorkeers, *et al* 1996). The exact reasons for high P levels in Bukoba soils are not well explained. However, Floor *et al* (1990) cited by Touber and Kanani (1994) and Morbeg (1974) explained that it could be due to certain rock strata or volcanic ash depositions. Follet, (1981) also explained that the quantity of organic phosphorus in the soil increases with increasing organic carbon/matter. Since in all sites, the organic carbon was high, this could probably be the reason of high P level in this study.

Leguminous plant species had little impact on soil potassium across all sites. The *rweya* soils of Bukoba are medium to highly acidic. Exchangeable potassium is known to be affected by many factors such as soil pH, temperature, wetting/rainfall and type of colloid (Miller and Donahue, 1995). Since the study area was in the high rainfall zone of Bukoba with acidic soils, it was likely that the effect of legumes on exchangeable potassium could not be realized given a short duration of which the research was done.

In general the potential of legumes on soil fertility improvement have been demonstrated by this study.

5.2 Agronomic data

5.2.1 Number of plants surviving in the second month

The average germination of legumes in this study was 70.12%. The average number of plants surviving in the first month was 60.21±1.18, 59.07±1.18 and 29.47±1.18% for site one, two and three respectively. In the second month the average number of plants were 56.78±1.18, 52.25±1.18 and 14.98±1.18% for site one two and three respectively. *C. ternatea* and *M. atropurpureum* had disappeared in site three and only 7% *D. intortum* plants were surviving in oversown treatments. It has been observed that, poor germination and survival of legumes are among the reasons for low adoption of incorporating legumes in farming systems in the tropics (Tesha and Mtengeti, 1995; Giller, 2001). Other reasons are; failure of legumes to compete with companion grasses, soil temperature and moisture, improper drying and seed purity (Skerman *et al* 1988; Trannin *et al*, 2000; Crowder and Chheda, 1982; Kemp *et al* 2000).

Site three had the poorest survival percent among all sites in the study area. It has been documented that, legumes require some amount of mineral nitrogen before they are able to build their own reserve. Legumes growing on nitrogen deficient soils usually exhibit a period of nitrogen starvation after the seed reserves are exhausted and before nodules become fully effective (Skerman *et al*, 1988; Trannin *et al*, 2000). It has also been shown that, some tropical legumes such as *M. atropurpureum*, *C. pubescens* and *C. ternatea* require more fertile soils to grow well or even to survive while others like stylo may grow and survive in very infertile soils (t'Mannetje *et al*, 1980). Thus failure of some legumes to survive in some parts of very poor *rweya* was an evidence that they require mineral fertilizer to enhance their ability to compete and adapt to poor soils. It has also been noted that in grass-legume mixtures it oftenly occurs that, some of the more desired legume species are less prevalent in the first season since some are slow in becoming established. These legumes include; *C. pubescens*, *G. wightii*, *M. atropurpureum* and *P. phaseoloides* (Crowder and Chheda, 1980). Furthermore, *rweya* soils are highly acidic. Soil acidity is one of the factors limiting legume nodulation and hence failure to compete with grasses. Soil acidity usually reflects small, K, Mg and Ca concentrations and large Mn and Al concentrations. High hydrogen concentration is usually harmful to the survival of rhizobia (t'Mannetje, 1980). Addition of fertilizer in poor soils such as that of *rweya* is encouraged in order to assist legumes to meet their demand before successfully being established (Skerman *et al*, 1988; Crowder and Chheda, 1982). Thus failure of the legumes to establish in poorer part of the *rweya* could be due to reasons explained above.

5.3 Dry matter yield

5.3.1 Dry matter yield of the natural and mixed pasture samples in the first and second harvest

Dry matter yield of the pastures in the first harvest in site one ranged between 805.9±188 and 1291.08±188kgDM/ha. In the second harvest, DM yield ranged between 1167.99±188 to 2564.61±188kgDM/ha. In site two in the first harvest, DM yield ranged between 904.12±184 to 1330.09±184kgDM/ha and in the second harvest, it ranged between 1013.63±184 to 2436.35±184kgDM/ha. In site three during the first harvest, DM yield ranged between 778.48±162 to 1384.36±162kgDM/ha and it ranged between 1353.53±162 to 2190.96±162kgDM/ha in the second harvest. Generally higher DM yields were observed in the second harvest. The control treatments yielded lower than the oversown treatments in all sites. This clearly showed that, oversowing leguminous plants species increased DM yield of the natural pastures.

On the overall, site one had higher DM yields than the other sites. This is because yield is affected by soil fertility status and species composition (Crowder and Chheda, 1982). Thus site one formerly a dairy centre, had higher total nitrogen (0.39%) thus it was expected to yield higher than the other sites. Likewise, site three was an abandoned place dominated by *Eragrostis olivacea* and *E. kagerensis*, which are locally used as indicator grasses of very poor soil fertility had the lowest yield. The results from this study has indicated that, oversowing leguminous plant species into natural pastures increased the dry matter yield at varying levels in the different sites. During the first harvest, the dry matter yield increase in site one was 4.08%, while in site two the increase in dry matter yield was 20.33% and in site three the increase in dry matter yield was 25.2%. The average increase in dry matter yield in the first harvest in all sites was 16.54%. In the second harvest, the dry matter yield increase was as follows 10.88, 12.05 and 18.46% for site one two and three respectively. The mean increase in dry matter yield in the second harvest was 13.8%. Rukanda and Lwoga (1981) found oversowing to have increased DM yield by 30% in a *Themeda-Hyperrhenia* dominated grasses in Morogoro. Also, although there have been no previous yield studies on DM yield of *rweya* pastures, the results observed in the present study compares well with the results obtained from other studies done elsewhere. Shem (1996) obtained a yield of 0.5 to 5.2 t/ha in Shinyanga and Mestawet (2000) obtained a yield of 1.25 to 1.79 t/ha in legume-oversown treatments also in Shinyanga during wet season. The treatments in this study were also harvested during the rainy season. Thus there is an agreement between the results in this study with those of other studies in the increase in DM yield as a result of oversowing leguminous plant species in natural pastures.

Basing on the yield figures obtained from this study, it was evident that, oversowing has indeed improved the dry matter yield of the indigenous pastures.

5.4 Nutritive value of natural and oversown pastures

5.4.1 Nutritive value of mixed and natural pasture in the first and second harvests

Nutritive value of forage refers to its chemical composition, digestibility and nature of the digested product (Crowder and Chheda, 1982). One of the reasons of inclusion of legumes into natural pastures is to increase the nutritive value (Tothill, 1986; Rukanda and Lwoga, 1981; CIAT, 1992).

In site one, during the first harvest, the CP content of oversown natural pasture ranged between 7.74±0.64 and 11.28±0.64%. Natural pastures alone had the lowest CP content than the mixed pastures. In site two, the CP content of the natural pasture alone was 5.26±0.43% and *C. pubescens* oversown treatment, which had the highest in the site had 8.17±0.31%. In site three, the CP content ranged between 4.62±0.29 to 7.49±0.29%.

In the second harvest in site one, the CP content observed was as follows: 9.14±0.64, 8.84±0.64, 8.29±0.64, 7.37±0.64, 7.17±0.64% for *C. pubescens*, *D. intortum*, *P. phaseoloides*, *C. ternatea*, *M. atropurpureum* oversown treatments respectively and the control treatment had 7.82±0.64%.

In site two during the second harvest the CP content ranged between 5.44±0.43 to 8.9±0.43% and in site three, the range was 5.81±0.29 to 7.11±0.29%.

It was generally observed that oversowing leguminous plant species increased CP content of forages at varying levels in different sites. During the first harvest, in site one oversowing leguminous species increased the CP by 21.28%. In site two oversowing increased the CP content by 31% and in site three, CP content increased by 35%. In the second harvest, CP increase was 4.16, 31.54 and 13.33% for site one two and three respectively. Studies done in other areas have also shown that there have been increases in the CP content of tropical pastures, which are characterized, by lower CP contents as a result of oversowing (Milford, 1967; Gohl, 1981; Crowder and Chheda, 1982; Giller, 2001). Results from this study have demonstrated that oversowing leguminous plant species increased the protein content of forages to the minimum threshold of protein that is required by ruminants for ruminal microbial activity initiation which ranges from 6.5 to 7% (Milford and Minson, 1966; Tothill, 1986; Van Soest, 1994). These results compares well with other studies done elsewhere. Kretschmer (1966) quoted by Mero (1985) reported that introducing *M. atropurpureum* at 1.1kg/ha on 25cm grid raised the protein level of Pangola grass from 4.7 to 7.1%, and at 11kg/ha of seed, the protein content was 11.2% for the mixture and 5.8% for Pangola alone. Also, significant increases in milk production up to 20% have been obtained on grass/legume pastures compared with grass only. 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 attributed to the presence of forage legumes in the pasture have also been observed with a range of pastures with different legumes in different ecosystems of the tropics (CIAT, 1992). In Puerto Rico, oversowing *Puereria phaseoloides* (Tropical kudzu) into molasses grass (*Melinis minutiflora*) raised the protein level from 4.2% to 8%

with 60% legume by weight in the mix (Skerman *et al.*, 1988). In an experiment conducted by Rukanda and Lwoga (1981) for six months by oversowing *M. atropurpureum* and *Stylosanthes guyanensis* in a *Themeda-Hyperrhenia* dominated natural grassland at Morogoro, it was found that oversowing increased total DM yield by 30%. In the same experiment it was found that, the mean CP content in a period of six months increased by 12% and mean *In vitro* DM digestibility increased by 7% and live weight gain of grazing dairy heifers increased by 112%. Mestawet (2000) also found that oversowing legumes increased the CP content of natural pastures by 17 to 49%. The higher CP values in oversown treatments are due to benefits usually obtained by companion grasses from legumes and increased nitrogen content in the soil as a result of legume incorporation Ta and Faris, (1987b) cited by Trannin, 2000 and Skerman *et al.*, (1988).

The mean ash content was higher in site one while it was lower in site three. The values found in this study are comparable to those found by other workers. Mestawet (2000) and Mero (1985) found ash values ranging between 10.8 to 12.2% for oversown and control treatments respectively. They are also comparable to those found by Rubanza (1999) and Kakengi (1998) in Shinyanga region. Ash values in the second harvest were not significantly different from those of the first harvest. However it has been reported that, high ash content, high phenolic compounds in plants and low DM contents are some of the non-cell wall constituents which limit intake in tropical forages (Meissner *et al*, 1992b; Meissner and Paulsmeier, 1995 and Pienaar *et al*, 1993). Thus high ash contents are not desirable.

NDF values in site one were 74.89±1.72% for the control treatment, which was higher than the other treatments in the site. Other treatments had values as follows: natural oversown with *C. pubescens* 69.03±1.72%, natural with *P. phaseoloides* 69.73±1.72, natural with *C. ternatea* 69.46±1.72, natural with *M atropurpureum* 72.79±1.72 and natural with *D. intortum* 73.79±1.72% respectively. In site two again the control treatment had higher NDF value than the other treatments. The values ranged between 71.63±1.25% observed in *P. phaseoloides* oversown treatment to 79.68±1.25% in the control treatment. The same trend was observed in site three. Generally, higher NDF values were observed in site three while lower values were reported in site one. This could probably be attributed to the influence of soil fertility on chemical composition of forages (Van Soest, 1994). It has also been reported that higher cell wall components such as NDF, ADF and ADL are indicators of poor forages (Whiteman, 1980; Van Soest, 1994, McDonald, *et al.*, 1995). However, the results observed in the current study are comparable to those reported by other authors on tropical forages. McDonald *et al* (1995) and Van Soest (1994) reported NDF values of 64 to 74.1% for poor tropical forages. Mestawet (2000) reported NDF values ranging between 76.87 to 79.73% for the control and oversown forages in Shinyanga region.

Generally, it has also been observed that tropical forages (C_4plants) have a relatively higher fraction of NDF content compared to temperate (C3 plants) legume and grass forages (NRC, 1989; Van Soest, 1994; Strudsholm *et al*, 1995). There is high variation in tropical forages both in CP and NDF contents depending on the species, degree of maturity, physical form and method of processing/preservation. There is a general agreement that legumes have higher CP content but lower NDF content than grasses and crop residues (Mgheni, 2000).

The results on ADF from the study in all sites in the first and second harvests ranged between 37.22±0.89 to 50±0.89%. The control treatments had higher ADF values than the oversown treatments in all sites. Natural pasture oversown with *P. phaseoloides* in site two had the lowest ADF values in all sites. The values are lower than those found by Mestawet (2000) in Shinyanga who found values ranging from 50 to 52.2% for the control and oversown treatments respectively. However, Van Soest (1994), Chenyambuga (1995) and Kakengi (1998) reported ADF values for different tropical forage hays ranging from 36 to 50.9%. Thus the results on ADF were within the range reported for tropical forages.

ADL content ranged between 4.54±0.59 to 10.26±0.36%. In site two and three, the control treatments had higher ADL than the oversown treatments. Within sites the ADL content was not different for the oversown treatments. The ADL contents were generally higher than those reported by Mestawet (2000) and Rubanza (1999) who found values of 4.76 to 4.92% and 1.19 to 2.05% for dry season forages respectively in Shinyanga. Van Soest (1994) explained the factors affecting forage quality to be temperature, light, water, fertilization and soil. Others are diseases and various plant stresses which influence composition. Poor soil fertility and high rainfall may be cited as the reasons of high silica contents of Bukoban forages.

Generally the nutritive value of the treatments in all sites were higher in the first harvest than in the second harvest. The possible reason could be age. Whiteman (1980) and Van Soest (1994) reported that, the proportions of digestible components of tropical forages such as soluble carbohydrates, proteins and other cell contents tend to decline with maturity and the proportions of lignin, protected cellulose, hemicelluloses and other indigestible fractions increase. Hogan *et al* (1969) cited by Mero (1985) studied the composition, intake and digestion of *Phalaris tuberosa* forage that have been harvested at three stages of maturity. Cell wall constituents increased from 43.6 to 74.9% and nitrogen content decreased from 4.18 to 1.8% as plant matured. Both authors noted that advancing stage of maturity was associated with decreased food intake, decline in digestibility of organic matter, nitrogen and structural carbohydrates. They also noted that young fresh plants have higher CP content than mature old plants. Thus the findings of this study in the first and second harvests agree with what was expected from plants at different stages of maturity.

From the results obtained in this study, it was evident that oversowing legumes into natural pastures improved the nutritive value of companion grasses. Most improvements were seen in higher CP and lower NDF and ADF. There was also an influence of site on chemical composition of oversown forages where site one which was relatively more fertile than the others had higher values and site three which was the poorest had lower values.

5.5 Digestibility

5.5.1 *In vitro* dry matter and organic matter digestibility of natural and mixed samples during the first and second harvests

In the first harvest, *In vitro* dry matter digestibility in all sites ranged from 28.54±3.11 to 41.59±3.11% in all sites for the control and oversown treatments. In all sites the control treatment had the lowest IVDMD. These findings are higher than those found by Mestawet (2000) for oversown treatments in Shinyanga. However they are within the range reported by Van Soest (1994) who gave *In vitro* dry matter digestibility values ranging from 45 to 85% for tropical forages. Crowder and Chheda (1982) reported *In vitro* dry matter digestibility of forages to be within 35 to 40%. In site one, oversowing leguminous species increased the *In vitro* dry matter digestibility by 4.08%. In site two and three, the increase in IVDMD as a result of oversowing leguminous plant species was 20.33% and 25.2% respectively. In the second harvest the range of DM digestibility for oversown treatments in all sites ranged from 30±3.11 to 38.74±1.81%. The range for the control treatments across sites was 28.54±2.13 to 32.52±1.81%. In site one, the increase in IVDMD resulting from oversowing legumes in natural pasture was 10.88% while there was an increase of 12.05% in site two and 18.46%in site three. On average, oversowing legumes increased the *In vitro* dry matter digestibility by 13.8% across all sites in the second harvest. Rukanda and Lwoga (1981) reported an increase in DM digestibility of 7% as a result of oversowing leguminous plant species in Morogoro. Mestawet (2000) found the increase in IVDMD for oversown treatments to be in the range of 9.99 to 13.7% for the wet season forages in Shinyanga. Thus the values found in the current study are within the range found in tropical forages.

The *In vitro* organic matter digestibility in the first harvest ranged from 42.45±2.49 to 55.98±3.14% in all sites. The highest value was observed in site two where *M. atropurpureum* oversown treatment had 55.98±3.14% while *C. pubescens* in site one and *P. phaseoloides* in site three had the lowest IVOMD with 51.48±1.66, 51.96±3.14 and 51.07±2.49% respectively. Among the control treatments, the control in site one had higher values (47.46±1.66%). There was an increase in IVOMD of oversown treatments compared to control treatments in all sites. The increases were 10.4, 13.01 and 18.41% in site one, two and three respectively. The average increase was 13.94%. The values obtained from this study are generally higher than those found by Mestawet (2000) in Shinyanga, who found values ranging between 27 to 48% but they are within the range reported by Crowder and Chheda (1982) and Van Soest (1994) who reported values ranging from 38 to 75%. The increase in IVOMD is comparable to those reported by Rukanda and Lwoga (1981) who found an increase of 12% in dry matter digestibility over a six months period resulting from oversowing *S. guyanensis* and *M. atropurpureum* into *Themeda-Hyperrhenia* dominated grasses in Morogoro and Mestawet (2000) who also found values ranging from 10 to 13.13.7% in Shinyanga region. However, the IVOMD results of the control treatment especially in site two seem to be contradictory. It is known from literature (Van Soest, 1994; Milford, 1967; Crowder and Chheda, 1982) that digestibility is influenced by chemical composition of the feedstuff especially the protein content of the feed. The control treatment in site two had the lowest CP content among the treatments in the site. It was thus expected to have lower DM and OM digestibility than its counterparts, but on the contrary it had values, which are not significantly different from the oversown treatments. The reason for this was not clear. However, *In vitro* technique is said to have some shortcomings such as variations in microbial populations, sample size, preparation and storage, particle size, pH of the medium during incubation and the procedures, duration of fermentation, dilution rate and the quality and source of rumen liquor. It has also been observed that, since a large number of samples are involved, an error at one stage will influence results obtained in the subsequent stages. (Minson *et al* 1976; Chenyambuga, 1995). This could probably be the cause of this anomaly.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

Basing on the results obtained from this study, the following are the conclusions:-

- Legume survival and persistence are crucial elements for successful introduction of legumes in a farming system for improvement of herbage quality
- Oversowing has improved dry matter yield of indigenous pastures
- Mineral fertilizer application especially potassium is necessary during sowing legumes due to lack of this mineral in *rweya* soils
- Oversowing legumes improved soil nitrogen and phosphorus status but had no effect on potassium
- *Puereria phaseoloides* and *Centrosema pubescens* performed well across all experimental sites. They had higher DM yields and nutritive value. They can be used to improve herbage quality of *rweya* in Bukoba high rainfall areas.
- Some legumes such as *M. atropurpureum* and *C. ternatea* are slow to establish and they usually perform well in their second year of establishment and some legumes perform better in fertile soils
- From the results obtained in this study, it is evident that oversowing legumes into natural pastures improved the nutritive value of companion grasses. Notable improvements were seen in high CP content and low NDF and ADF. There was also an obvious influence of site on chemical composition of oversown forages where site one which was relatively more fertile than others had higher values and site three which was the poorest had lower values

6.2 Recommendations

- Due to differences in adaptation of legumes to different environment, there is a need to screen more legumes in order to find the most suitable in the *rweya*
- For *rweya* with poor soil fertility, mineral fertilizer should be used during sowing and early growing period to assist legumes to compete with companion grasses before they start fixing nitrogen
- *Puereria phaseoloides* and *Centrosema pubescens* are recommended for oversowing in different types of *rweya*. *D. intortum* has potential of surviving in *rweya* but it needs initial fertilization with mineral fertilizers before being able to fix its own nitrogen
- Since *rweya* is usually a communal grazing land in most parts of Kagera region, proper grazing management should be instituted in order to realise the benefits of pasture improvement by oversowing. Different actors such as District Councils and Central government should be involved in enacting laws and by-laws
- Legumes can be used for supplementing lactating animals to alleviate acute shortage of supplementary feeds affecting the majority of dairy animal keepers in Kagera
- The technology needs to be demonstrated on-farm in order to increase awareness among farmers in order to increase its adoptability
- Ease of availability and adequate legume seeds is important for success of this technology

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APPENDICES

Appendix 1: Description of legume species used in the study

Centrosema pubescens

Common name: Centro

Description: This is a vigorous, trailing twining and climbing perennial herb. In pure stand forms a compact dense cover 40-45 cm high in 4-8 months from sowing. It is very leafy and it is widely distributed in the tropics. Temperature requirement is 25.6°C with low frost tolerance.

Rainfall requirements: In wet tropics it requires rainfall in excess of 1750mm or irrigation but it also grows in areas receiving 750mm or more. It is drought resistant by dropping leaves in dry period. It grows in wide range of soils even those with pH as low as 4.0. The optimum pH however is 4.9-5.5. The legume produces abundant nodules although it has some specificity toward rhizobium. It also grows well with grasses of medium height.

Nitrogen fixing ability: 100-235 kg N/ha. It has a good response to defoliation. DM yields: 4950 kg DM/ha/year. Feeding value: The legume is very valuable for grazing and as a hay crop. Digestibility: DM 53.5%, OM 53.2%, Crude protein 62.4%, Ether Extract 44.3%, Nitrogen Free Extract 61.3%, Crude Fiber 39.5% and Ash 56%. It is fairly palatable (FAO, 1994).

Desmodium intortum

Common name: Greenleaf desmodium.

Description: This is a large trailing climbing perennial with root at the nodules and has deep taproot and leafier. It originated in northern parts of South America and is native in Panama, Columbia, Guatemala, Venezuela, Ecuador and Peru. It has spread throughout the tropics and it is being widely tested for fodder value. The optimum temperature for growth is 25-30°C. And it is able to withstand hot weather though it is susceptible to heavy frost and water logging. Rainfall requirement is above 875mm a year. The legume performs well in slopes. It can grow in a wider variety of soils with pH of 5.0 and above but it has no tolerance to salinity.

Desmodium has specificity in terms of rhizobia requirement. In order to establish well it requires P, K, Mo and Zn. It can fix nitrogen in the range of 300-375 kg N/ha/year as it was recorded in Hawaii. DM yield ranges from 12,000 to 19,000 kg DM/ha with 18.8% CP approximately. The digestibility is 54.08% and it is highly palatable (FAO, 1994).

Clitoria ternatea

Common names: Butterfly pea, Kordofan pea.

Description: Is a climber, shrubby at base, five to seven leaflets elliptic to narrowly lanceolate flowers; solitary deep blue occasionally pure white. Distributed throughout the tropics. Grows well at areas with low frost, can climb tall grasses and crops. It grows from sea level to 1800 m with rainfall requirement of 400 - 1500 mm.

It is fairly drought tolerance but do not tolerate flooding. The legume grows in different varieties of soil, with some tolerance to salinity and able to grow in high pH soils. It has rhizobia specificity. It has good seeding vigor and grows rapidly in moist weather, producing a dense cover 4-6 months after seeding. Suppresses weeds very well even with tall grasses. DM yield: In Zambia Van Rensburg (1967) found DM of 3330 kg/ha in the first year of establishment, but usually yields decline gradually year after year. It is very palatable.

Macroptilium atropurpureum

Common name: Siratro

Description: Deep-rooting perennial with trailing pubescent stems. It is well distributed in the tropics. Naturally it occurs in Central and South America. It grows at 25. 5- 30°C and at height of 1600m. Rainfall requirement is above 850mm. It grows in wide variety of soils except poorly drained ones. pH range is 4.5-8.0. It nodulates freely with native rhizobia but seed must be inoculated at sowing with inoculum of cowpea type. Requires Molybdenized Super phosphate up to 500 kg/ha. On acid soils Molybdenum may be unavailable and addition of calcium to raise pH is advised. It grows vigorously in hot weather and is most productive in mid-summer. Nitrogen fixing ability 100-75kg/ha/year.

DM yields: In Zambia average DM yield for two years was 7960 kg/ha (van Rosenberg, 1967). In Florida DM yield was 11610 kgDM/ha/year when grown with pangola grass Krestschmer (1966) as quoted by Skerman *et al.*, (1988). It is highly palatable with digestibility of 50.4%.

Puereria phaseoloides

Common name: Tropical kudzu

Description: Vigorous twining and climbing, slightly woody, hairy perennial legume, deep rooting and rather slender. Its main stems are about 0.6 cm in diameter and may extend for 5 to 6 metres. They may root at the nodes and from the nodes a number of lateral or secondary branches are formed. These intertwine and may result in a tangled mass of vegetation 60 to 75 cm deep within eight to nine months of sowing. The young shoots are densely covered with brown hairs. It is native to south-east Asia Malaysia and Indonesia and is now widespread throughout the wet tropics.

Rainfall requirements: Grows best in a rainfall exceeding 2 500 mm or in swampy land in areas of lower rainfall. In Tanzania, it grows in a minimum rainfall of 850 mm as a cover crop in sisal but grows better at 1 160 mm at Mlingano, Tanzania (Hopkinson, 1969).

Soil requirements: Has a wide range in soil adaptability, from sands to clays, although it does not grow well in tight heavy clays. Does well on sands and clays in Suriname, on latosols in Tanzania and north Queensland, Australia. Loustalot and Telford (1948) found a pH of 4 to 5 to be best. Fe deficiency showed at a pH of 6 to 8. N production was greatest at a pH of 4. Landrau *et al.* (1953) quote good growth at pH 4.5 on a lateritic soil, and at pH 4.6 to 5.1 in a clay. Smith recorded best growth at pH 5.5 and Chandler (1951) but other co-workers increased growth by liming from pH 5.3 to 6.5 and, in the greenhouse, from pH 5.2 to 7.5. Molybdenum release may have been responsible. It is not tolerant. Rhizobium requirements: A promiscuous species; nodulates with the cowpea type of Rhizobium, strain CB756 in Australia.

However, Bowen (personal communication) obtained nearly double the yield from inoculated plants (as compared with the uninoculated control). Spreads mainly by runners and in this way colonizes widely on suitable soils with adequate rainfall

Nitrogen fixing ability: Schofield (1945) found puero to be a better contributor of nitrogen to the soil than calopo, Centro and stylo. After 18 months' growth, it was ploughed into the soil. The nitrogen content of a similar soil under bare fallow was 34.4 ppm, and in the soil into which puero was ploughed it was 171.8 ppm compared with 71.7 for Centro, 66.7 for calopo and 54.5 for stylo. Hopkinson (1969) found that puero used as a green cover in sisal increased the fibre yield by 26 percent and equalled the yield with puero plus nitrogen. Rijkebusch (1967) found that puero had the same effect with sisal as the application of 635 kg. N/ha in Tanzania. Oke (1967b) showed that puero fixed 9.3 mg N/plant/day, compared with 3.8 mg for Calopogonium, and transferred 92 percent of the fixed nitrogen to the plant tops, compared with 87 percent for calopo. Bruce (1967) found that an elephant (napier) grass/ puero pasture added 143 kg. N/ha/year to the top 15 cm of soil and raised the protein content of the grass by 7.1 percent. In puero stands, puero is self-mulching and adds considerable nitrogen by mineralization of leaf fall (Horrell, 1958).

Response to defoliation: It is moderately tolerant of defoliation, and recovers well after lenient grazing. Vicente-Chandler, Caro-Costas and Figarella (1953) found that cutting at 25 cm instead of 10 cm favoured puero in a molasses grass/puero mixture and gave better rooting and drought resistance.

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Grazing management: Should be leniently grazed at all times to maintain the botanical composition of the pasture, as it is very palatable when selectively grazed. If it dominates the pasture mixture, grazing pressure can be increased.

Appendix 2: Field layout

6m	1m m1m	6m	1m	6m
REP I		REP II		REP III
L_2 O		L_2 O		L_4 A
L_2 A		L_3 O		L_1 O
L_5 O		L_1 O		L_2 A
L_4 O		L_1 A		L_4 O
L_1 A		L_5 A		L_3 O
L_3 O		L_4 A		L_2 O
L_1 O		L_3 A		C
L_5 A		L_4 O		L_5 A
L_4 A		C		L_5 O
L_3 A		L_2 A		L_3 A
C		L_5 O		L_1 A

Total area = 39.6 x 20 m

Plot size = 3.6m x 6m

TREATMENTS:

1. L_1 A
2. L_1 O
3. L_2 A
4. L_2 O
5. L_3 A
6. L_3 O
7. L_4 A
8. L_4 O
9. L_5 A
10. L_5 O
11. C

CODES:

L1= *Centrosema pubescens*

L2= *Desmodium intortum*

L3= *Macroptilium atropurpureum*

L4= *Clitoria ternatea*

L5= *Puereria phaseoloides*

C= Control

A= Alone

O= Oversown

Three sites selected using the following criteria:

1. Good *rweya*
2. Medium *rweya*
3. Very poor *rweya*

CRBD with the following treatments:

Legumes alone = 5 treatments

Legume + Pasture =5 treatments

Pasture alone 1 treatment

Appendix 3: ANOVA tables for DM yield, chemical composition, Germination percent and soil data

ANOVA table for germination percent

Dependent Variable: Germination percent

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	97.01892667	48.50946333	7.68	0.0050
SPP	4	261.09023333	65.27255833	10.34	0.0003
SITE*SPP	8	356.95420667	44.61927583	7.07	0.0006
Error	15	94.73285000	6.31552333		
Corrected Total	29	809.79621667			

R-Square	C.V.	Root MSE	Germ perc. Mean
0.883016	3.583872	2.51307050	70.12166667

ANOVA table for chemical composition of natural and mixed pastures

Dependent Variable: DMYIELD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	452387.68895069	226193.84447534	1.31	0.2771
SPP	5	5571074.40472567	1114214.88094513	6.44	0.0001
Harvest	1	12514214.81455040	12514214.81455040	72.28	0.0001
SITE*SPP	8	2145328.72580208	268166.09072526	1.55	0.1558
SPP* Harvest	5	808041.30648681	161608.26129736	0.93	0.4646
SITE* Harvest	2	857292.17852845	428646.08926423	2.48	0.0912
Error	72	12465192.15113530	173127.66876577		
Corrected Total	95	37432248.93619570			

R-Square	C.V.	Root MSE	DMYIELD Mean
0.666993	27.77679	416.08613143	1497.96354167

Dependent Variable: NDF

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	238.18668542	119.09334271	18.41	0.0001
SPP	5	211.55889931	42.31177986	6.54	0.0001
Harvest	1	145.28372042	145.28372042	22.46	0.0001
SITE*SPP	8	69.72648125	8.71581016	1.35	0.2347
SPP* Harvest	5	82.22201597	16.44440319	2.54	0.0356
SITE* Harvest	2	50.76691875	25.38345938	3.92	0.0241
Error	72	465.77538125	6.46910252		
Corrected Total	95	1234.52179062			

R-Square	C.V.	Root MSE	NDF Mean
0.622708	3.422963	2.54344304	74.30531250

Dependent Variable: ADF

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	242.97365000	121.48682500	30.00	0.0001
SPP	5	251.54981806	50.30996361	12.42	0.0001
Harvest	1	5.05760667	5.05760667	1.25	0.2675
SITE*SPP	8	32.86346667	4.10793333	1.01	0.4332
SPP* Harvest	5	66.17117917	13.23423583	3.27	0.0103
SITE* Harvest	2	86.09857778	43.04928889	10.63	0.0001
Error	72	291.59702778	4.04995872		
Corrected Total	95	963.04972396			

R-Square	C.V.	Root MSE	ADF Mean
0.697215	4.449505	2.01245092	45.22864583

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Dependent Variable: ADL

Source          DF        Type III SS        Mean Square     F Value    Pr > F
SITE             2        87.61891389        43.80945694     35.26      0.0001
SPP              5        97.36542639        19.47308528     15.67      0.0001
Harvest          1        344.01781500       344.01781500    276.90     0.0001
SITE*SPP         8        51.99785833        6.49973229      5.23       0.0001
SPP* Harvest 5            39.09030972        7.81806194      6.29       0.0001
SITE* Harvest2            32.01040833        16.00520417     12.88      0.0001
Error           72        89.45140833        1.24238067
Corrected Total 95        809.36791563
   R-Square               C.V.             Root MSE            ADL Mean
   0.889480               11.90318         1.11462131          9.36406250

Dependent Variable: CP

Source          DF        Type III SS        Mean Square     F Value    Pr > F
SITE             2        85.11654583        42.55827292     56.65      0.0001
SPP              5        60.89507500        12.17901500     16.21      0.0001
Harvest          1        3.45120167         3.45120167      4.59       0.0355
SITE*SPP         8        11.00461806        1.37557726      1.83       0.0851
SPP* Harvest     5        7.70451944         1.54090389      2.05       0.0816
SITE* Harvest 2           13.90392361        6.95196181      9.25       0.0003
Error           72        54.09321806        0.75129470
Corrected Total  95       234.86946250
   R-Square               C.V.             Root MSE            CP Mean
   0.769688               11.29070         0.86677257          7.67687500

Dependent Variable: ASH

Source          DF        Type III SS        Mean Square     F Value    Pr > F
SITE             2        34.68712986        17.34356493     8.21     0.0006
SPP              5        12.91258819        2.58251764      1.22       0.3074
Harvest          1        0.14751042         0.14751042      0.07       0.7923
SITE*SPP         8        31.42513125        3.92814141      1.86       0.0799
SPP* Harvest 5            26.57009375        5.31401875      2.52       0.0372
SITE* Harvest2            3.43432431         1.71716215      0.81       0.4476
Error           72        152.08847014       2.11233986
Corrected Total  95       261.00159896
   R-Square               C.V.             Root MSE            ASH Mean
   0.578289               10.79767         1.45338910          6.98822917

Dependent Variable: IVDMD

Source          DF        Type III SS        Mean Square     F Value    Pr > F
SITE             2        91.22668100        45.61334050     2.62       0.0799
SPP              5        478.28827548       95.65765510     5.50       0.0003
Harvest          1        10.62768907        10.62768907     0.61       0.4370
SITE*SPP         8        146.69977999       18.33747250     1.05       0.4051
SPP* Harvest 5            85.04726249        17.00945250     0.98       0.4375
SITE* Harvest2            167.09711381       83.54855690     4.80       0.0112
Error           68        1182.38848612      17.38806597
Corrected Total    91        2216.60929022
  R-Square                C.V.             Root MSE            IVDMD2 Mean
  0.766578                11.55887         4.16990000          36.07532609
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Dependent Variable: IVOMD

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	74.48467005	37.24233503	2.04	0.1383
SPP	5	611.07026638	122.21405328	6.69	0.0001
Harvest	1	7.08165616	7.08165616	0.39	0.5357
SITE*SPP	8	102.73543352	12.84192919	0.70	0.6880
SPP* Harvest	5	20.63106721	4.12621344	0.23	0.9501
SITE* Harvest	2	99.43575788	49.71787894	2.72	0.0731
Error	67	1224.46858358	18.27565050		
Corrected Total	90	2247.62337582			

R-Square	C.V.	Root MSE	IVOMD2 Mean
0.755216	8.486664	4.27500298	50.37318681

ANOVA table for soil chemical properties

Dependent Variable: PH

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	0.05202381	0.02601190	0.39	0.6864
SPP	5	0.47590389	0.09518078	1.41	0.2759
SITE*SPP	8	0.54983519	0.06872940	1.02	0.4626
Error	15	1.01130000	0.06742000		
Corrected Total	30	2.08719355			

R-Square	C.V.	Root MSE	PH Mean
0.685474	4.659486	0.25965362	5.57258065

Dependent Variable: OC

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	7.02762818	3.51381409	29.09	0.0001
SPP	5	0.64635091	0.12927018	1.07	0.4151
SITE*SPP	8	4.54389438	0.56798680	4.70	0.0049
Error	15	1.81156800	0.12077120		
Corrected Total	30	14.14846368			

R-Square	C.V.	Root MSE	OC Mean
0.871960	6.582410	0.34752151	5.27954839

Dependent Variable: N

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	0.20687895	0.10343947	115.65	0.0001
SPP	5	0.12836625	0.02567325	28.70	0.0001
SITE*SPP	8	0.02024006	0.00253001	2.83	0.0394
Error	15	0.01341600	0.00089440		
Corrected Total	30	0.41185497			

R-Square	C.V.	Root MSE	N Mean
0.967425	10.75649	0.02990652	0.27803226

Dependent Variable: P

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	2981.41206268	1490.70603134	44.98	0.0001
SPP	5	624.59428881	124.91885776	3.77	0.0207
SITE*SPP	8	755.31582771	94.41447846	2.85	0.0384
Error	15	497.16709100	33.14447273		
Corrected Total	30	5119.26388142			

R-Square	C.V.	Root MSE	P Mean
0.902883	35.26402	5.75712365	16.32577419

Dependent Variable: K

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SITE	2	0.05630045	0.02815023	24.95	0.0001
SPP	5	0.01798432	0.00359686	3.19	0.0370
SITE*SPP	8	0.00422950	0.00052869	0.47	0.8597
Error	15	0.01692400	0.00112827		
Corrected Total	30	0.10408297			

R-Square	C.V.	Root MSE	K Mean
0.837399	25.26153	0.03358968	0.13296774

SPE