SEASONAL VARIATION IN QUALITY AND QUANTITY OF *HYPARRHENIA RUFA,* A NATIVE GRASS IN DIAMPHWE CATTLE RANCH OF CENTRAL MALAWI, AFRICA

By

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To my family

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

ADF	Acid – detergent fiber
C3	Carbon 3
C4	Carbon 4
Ca	Calcium
Cl	Chlorine
Co	Colbat
CP	Crude protein
Cu	Copper
DM	Dry matter
Fe	Iron
HA	Herbage Accumulation
HM	Herbage Mass
K	Potassium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
NDF	Neutral – detergent fiber
OM	Organic matter
P	Phosphorous
PPM	Parts Per Million
S	Sulphur
Zn	Zinc

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The objective of the study was to evaluate the seasonal variation in quality and quantity of predominant native pasture forage *(hyparrhenia rufa)* at Diamphwe cattle ranch, from October 2011 to March 2012 as a basis for supplementation. Monthly changes in minerals, (CP), (ADF), (NDF), (IVDMD), (HM) and (HA) were analyzed. January, February and March had greater HM, $P < 0.05$ in the Lowlands. Lowlands had greater HA, $P < 0.05$ in December to January. There was no difference in ADF in both locations and also NDF did not differ, $P > 0.05$ but it was characterized by an increase in ADF and NDF as the season progressed. Greater IVDMD, $P < 0.05$ was observed in the Uplands in October and November but the month with the least digestibility was December. In October and November, Uplands showed greater CP concentration $P < 0.05$. CP, Na, S, and Cu, did not meet the requirement for beef cattle but Zn only met the requirement in March. Ca, P, K, Mg, Cl, Fe, Mo, Mn and Co met the requirement for beef cattle during the study period. The results also showed the importance of Lowlands for livestock production in the ranch although Lowlands constituted only a

small fraction of this landscape, they provided greater levels of herbage mass throughout the study period.

CHAPTER 1
INTRODUCTION

Diamphwe cattle ranch occupies 32,000 hectares of land and is in the central region of Malawi in the Dzalanyama forest reserve with coordinates of 14˚25's and 33˚30'E with an altitude of 1300-1650 m and at a distance of 80 kilometers southwest of Lilongwe the capital city of Malawi. There are two seasons in Malawi: The rainy season which extends from October to March and a dry period from April to September. The annual precipitation ranges from 763-1140 mm and temperatures range from -2˚C to 30˚C (Hodges 1983). This cattle ranch is owned by the government of Malawi and has a population of over four thousand (4,000) cattle. The main objective of the ranch is to produce steers for fattening and work oxen and also acts as a reserve for Malawi Zebu cattle genetic material.

Native grasses of which *hyparrhenia rufa* dominates are the primary source of nutrition for these cattle. Unfortunately, forages often do not provide all of the needed nutrients which cattle require throughout the year. Many incidences of mineral inadequacies in forages and soils have been reported which contribute to reproductive failure and low production rate (Vagas and Mc Dowell 1997).

The cyclic gain of cattle body weight with the onset of the rains and the loss of about 30% of this body weight during the dry season continues to be a major limitation to cattle production in Malawi (Mtimuni 1982). Recently solutions to the problem of the long dry season have been attempted with the introduction of improved forages in form of Rhodes grass and use of stored feed such as hay and corn silage.

Intensification of livestock production has brought about some nutritional problems. In spite of frequent dipping to control ticks to avoid tick borne diseases and application of some improved livestock management techniques, major problems still exist within the ranch. These problems include cyclic body weight gain and loss, 50% average calving rate, calf mortality of 20% and herd mortality rate of 5% from unknown causes (10 year average for Diamphwe cattle ranch).

Nutrient supplementation of cattle can help to alleviate problems associated with lack of forage quality and quantity (Grunes and Welch 1989). The balance of minerals is of vital consideration for animal health so far as their availability is concerned; the body can tolerate a deficiency of vitamins longer than a mineral deficiency (Grunes and welch 1989).

Mineral deficiencies or imbalances in soils and forages have long been held responsible for low production and reproduction problems among grazing animals (Mc Dowell 1985). Mineral deficiencies likely to affect production of grazing livestock in many regions of the world include the major elements calcium (Ca), phosphorous (P), magnesium (Mg) sodium(Na) sulphur(S) and the trace elements cobalt(Co), copper(Co) iodine (I), manganese(Mn), selenium(Se), zinc(Zn) and iron (fe) (Little,1982; Judson et al1987;Judson and Mc Farlane 1998). When nutrients are deficient the producer is justified to supplement. Currently there is a lack of information on the possible deficiencies of all nutrients and also mineral toxicities for pasture grazing animals at Diamphwe cattle ranch. This study was conducted to provide an objective basis for efficient and low cost nutrient and mineral supplementation, to identify grazing and supplementation strategies necessary to maintain long term herbage productivity and quality and livestock production within the ranch by; 1) Assessing forage nutrient concentrations during the rainy season, 2) Quantifying the dynamics of herbage yield and quality in the Upland and Lowland.

CHAPTER 2
LITERATURE REVIEW

Diamphwe Cattle Ranch

Diamphwe cattle Ranch was established in 1971 as part of Dzalanyama Forest Reserve within the 100,000 hectares of the forest reserve with a multipurpose form of land use to keep away poachers, bush fires and wood cutters from damaging the fauna and flora of the reserve and for production of good quality beef.(Dowsett and Lemaire 1989)

Vegetation of the Ranch varies from Brachystegia or savanna woodland to evergreen forests. It also forms part of Dzalanyama Range, a series of rocky hills running north-west south east along the border with Mozambique, which marks the water shed between Lake Malawi and the Zambezi river system. The eastern side of the Ranch is relatively flat, at about 1,300 m.

Diamphwe Cattle Ranch is characterized by rolling to flat topography with tropical savanna grassland characterized by short grasses and scattered shrubs and trees. The soil is deep well drained latosols on higher parts with poorly drained sand and clay soils in lowlands (Reynolds 2000).

Diamphwe Cattle Ranch practices controlled breeding, thus calving season starts in September or October depending on the time the bulls were introduced and it is done to take advantage of the rainy season when pastures are in abundance

Uplands and Lowlands

In the Uplands, where the attitude rise above 1300 m the soil is deep well drained latosols while in the Lowlands where the attitude is 750 m the soil is poorly drained sand

and clay. Lowlands are shallow and seasonally water logged depressions. (Hodges 1983).

The *Hyparrhenia rufa* pattern of growth is mainly controlled by regular grass fires in the Uplands, and in the Lowlands, the moisture of lower lying areas maintains a greener and more fire resistant margin to the remaining forest. The grass layer is depressed in the Uplands by relatively light crowned trees, which have the ability to coppice freely after cutting. The woodland varies in density from tall fairly open woodland to dense shrub. Grasses vary according to habitat, but are generally of medium height with low ground cover. When trees are cleared, the grasses become more vigorous and a dense vegetative cover results in the Uplands (Mitchell, 1987).

Lowlands are nearly treeless areas dominated by grasses or sedges with a buildup of organic matter with a hydromorphic soil horizon. Lowland's catchment also acts as a hydrological store, holding water and releasing it as a base flow to its headwater stream during the dry season. (Roberts 1988)

Constraints to Cattle Production

A major constraint to cattle production at Diamphwe cattle ranch is the long dry season which extends for six months from April to October. During the dry season, scarcity of grass becomes a problem in Malawi. Consequently nutrition has frequently been cited as the most limiting factor in cattle production in Malawi (Mtimuni, 1982).

Absence of legumes in natural pasture and the rapid decline of forage quality of native grasses as the rainy season progresses are factors hampering cattle production. When quality is low, forages alone may not support desired rates of animal performance (Moore and Sollenberger, 2002).

Low CP content of native grass is often below 7% of the minimum required for microbial activity and this limits intake (Milford and Mirson, 1965). High lignin content of tropical forage and reduced microbial activity caused by low dietary CP increases the retention rate of digesta in the rumen. Forage intake decreases and animals lose body weight because digestibility declines as lignin content increases (Minson, 1974).

NDF which constitutes lignin, cellulose and hemicellulose is inversely related to digestibility and intake potential of feed as it predicts the extent of biological degradation (Van Soest, 1991.) Concentration of NDF in C4 plants such as *hyparrhenia rufa* is 70% or higher and requires microbes.

Acid Detergent Fiber (ADF) which constitutes lignin and cellulose is used to predict digestibility and it's the poorly digested fiber fraction. Fiber is recognized as a required dietary ingredient for many herbivores. Two of the major functions of fiber are to stimulate rumination and salivation and to form a mat that functions as a filtering system and prevents a rapid passage of particles and loss of nutrients (Van Soest et al 1991).

This corresponds to NDF which is commonly used to asses forage quality. The NDF is better related to intake and gastrointestinal fill than any other measure of fiber thus expectation that the fiber requirement is better expressed in terms of NDF rather than ADF (Lewis et al, 1991). Ruminants generally and dairy cattle in particular require adequate coarse insoluble fiber for normal rumen function and maintenance of normal milk fat (Robertson et al 1991). Normal rumen function in dairy cattle is associated with adequate rumination and cellulose digestion. These events maintain rumen pH and cellulolytic microorganisms that characteristically produce the high acetate to propionate ratios needed for normal lipid metabolism in the cow. Daily rumination time is directly proportional to coarse NDF intake and related body size.

Animals gain body weight during the rainy season when there is a plentiful supply of forage which provides adequate protein and energy for the level of production for most local Malawi Zebu (Mtimuni, 1992). Animals lose body weight as forage quality progressively declines during the dry season. Animals may lose as much as 30% of their peak body weight in the dry season Mtimuni, (1982) severely affecting cowherd productivity.

The low calving rate observed at Diamphwe cattle ranch is partially caused by poor feed quality and quantity. On average, animals calve every other year due to low nutrient reserves in their body. Low calving rate (approximately 50%) coupled with an extended length of time to reach slaughter weight, stagnates productivity. The problem of low calving rate in animals is not unique to Diamphwe cattle ranch. Other livestock centers in Malawi experience the same problem indicating that low calving rate is wide spread in Malawi (Livestock and Meat Study 1983).

Efforts in livestock production in Malawi have been devoted to solving the problems of forage availability during the dry season. Considering the situation of plentiful low quality forage, Mtimuni, (1982) states that the major factor on such a pasture is the low CP content of grasses, which usually is below 7%, the maximum required for rumen microbial activity.

Energy becomes the second limiting factor because of reduced intake of low quality forage.

The gross energy content of forages is about 18 mega joules (MJ) per kg DM. Not all of this is available to the animals. After the forage has been digested, part of the energy is excreted in the urine and in methane that is produced during the fermentation process in the rumen. The animals also produce heat during digestion. Therefore with respect to the energy content of forage, a differentiation is made between Gross energy (GE), digestible energy (DE) which is GE minus energy of the undigested parts. Metabolisable energy (ME) which is DE minus energy in urine and methane and Net energy which is ME minus heat produced.

The net energy can be used by the animal to supply its various needs like maintenance of body functions, growth, lactation or gestation. A cow weighing 250 kilograms needs between 30 and 35 MJ metabolisable energy each day for maintenance, depending how far it walks. For this, it needs forage with about 1% nitrogen content and about 50% digestibility. To produce milk, a cow needs 5-7 MJ metabolisable energy per kg depending on fat content (Bayer 1998).

Ruminants differ little with respect to the energy they need to produce 1 kilogram of milk or to gain 1 kilogram live weight with the same fat content. What can differ however is the basic metabolic rate. The basic metabolic rate differs between animal species, for instance, it is much lower in camels than cattle of the same weight. It also differs between breeds. The higher, the genetic potential, the higher the basic metabolic rate the more feed is needed of high quality (Bayer 1998).

Although the available energy and protein of a feed are of vital importance to any animal, optimal production is only possible if there is an adequate supply of minerals (Mc Dowell 1985, Khan et al 2004).

In general, response to mineral supplementation has been observed during the rainy season when animals are growing rapidly there by increasing requirements. (Khan et al, 2004).To ensure efficient production, deficient nutrients must be supplied at required level so, thus Identification of deficient nutrients is then the first step in the management of livestock nutrition.

A manifested deficiency of minerals does not present a problem because it can be corrected using existing methods. The major problem is the sub optimal deficiency of minerals which can reduce growth rates and may cause low calving rate but is not readily apparent due to lack of specific clinical signs (Mtimuni, 1992). Very little is known about the growth characteristics and nutritional status of forage at Diamphwe cattle ranch. Therefore the objective of this study is to characterize the current status of minerals, CP, NDF, ADF, digestibility and growth characteristics of hyparrhenia rufa at Diamphwe cattle ranch during the rainy season.

Under nutrition is commonly accepted as one of the most important limitations to grazing livestock production in the tropics. The lack of sufficient energy and protein is often responsible for suboptimum livestock production. However numerous investigations have observed that cattle may deteriorate in spite of abundant feed supply (Mc Dowell and Arthington 2005).

Mineral imbalances (deficiency or excesses) in soils and forages have long been held responsible for low production and reproductive problems among grazing ruminants in tropics. Wasting diseases, loss of hair, depigmanted hair, skin disorders, non-infectious abortion, diarrhea, and anemia, loss of appetite, borne abnormalities, tetany, low fertility, and pica are clinical signs often suggestive of mineral deficiencies throughout the world (Mc Dowell and Arthington 2005). Minerals are vital for normal growth, reproduction, health and proper functioning of the animals body (Mc Dowell 1992). Minerals protect and maintain the structural components of the body organs and tissues and are constituents of body fluids and tissues as electrolytes. Minerals catalyze several enzymatic processes and hormone systems (Underwood and Suttle 1999). They maintain acid-base balance, water balance and osmotic pressure in the blood and cerebral spinal fluids. In fact, approximately 5% of the body weight of an animal consists of minerals.

Adequate intake of forages by grazing ruminants is essential to meet mineral requirements. Factors which greatly reduce forage intake, such as low protein less than 7% of DM and increased degree of lignification, reduce total minerals consumed (Mc Dowell and Arthington 2005). Ruminants on pasture may inadvertently consume large quantities of soil as a natural consequence of grazing (Healey 1974). Deliberate soil consumption on the other hand is classified as a form of pica, which is defined as animals chewing on objects and eating materials not considered to be natural feed stuff.

Concentration of mineral elements in forage is dependent upon the interaction of a number of factors including soil, plant species, and stage of maturity, yield, pasture management and climate.

The influence of soil chemistry and soil characteristics on the occurrence of mineral problems for grazing ruminants has been reviewed (Reid and Horvath, 1980) and of the total mineral concentration in soils, only a fraction is taken up by plants. Although mineral content of a soil ultimately depends on the parent rock from which the soil was derived, evidence indicates little relationship between soil chemistry and mineral composition of farm crops and vegetation growing on it (Underwood, 1981).

Consequently mineral intake by animals depends more on the type of plant and level of consumption than on the parent rock (Underwood et al 1981).

The most devastating economic effect of phosphorous deficiency is documented to be reproductive failure with phosphorous supplementation drastically increasing fertility levels in grazing cattle in many parts of the world (Mc Dowell 1985). In phosphorus deficient areas cattle are reported to produce a calf every other year or longer (Mc Dowell et al 1983). These animals require longer calving intervals to build up phosphorous reserves. P content of pasture mostly dominated by *hyparrhenia rufa* species decreases as the rainy season progresses from a high 0.2% P shortly after the beginning of the rainy season to as low as 0.05% (Mc Dowell et al 1992). The mineral elements most likely to be lacking under tropical conditions for ruminants are Ca, P, Na, C, Cu, I, S and Zn (Arthington, et al 2005).

Hyparrhenia rufa

Hyparrhenia rufa is a common native pasture plant throughout East Africa and Latin America used mainly for beef production. It is also used as coarse thatching grass in Africa. It is a perennial C4 grass commonly known as a yellow spike thatching grass in Southern Africa.

Hyparrhenia rufa is distributed throughout tropical Africa but it is wide spread in Central and South America. It favors well in a seasonally flooded grassland and open woodland and stands water logging and temporary flooding.

The height of the grass ranges from 60 – 240 cm with loose and narrow panicles of up to 50 cm long. It has slightly spreading and contiguous racemes with hairy spikelets of 3.5-5 mm long. Its flowering stems have little leaf and the sheaths of the leaves enclose about half the length of each internode. (Napper, 1965).

Hyparrhenia rufa requires precipitation of about 600 – 1400mm and it does well on retentive soils and is able to withstand a dry season of six months. It is sensitive to Aluminum soils and does well in black clays and latosols (Spain and Andrew 1977). In terms of photoperiod, *hyparrhenia rufa* is a short – day plant. Growth is retarted when day - length is less than 12 hours, 15 minutes during the growing season from October to April Rattry (1973). It stands close grazing if applied rotationally and not continuously and tolerates seasonal burning.

Hyparrhenia rufa has a good disease and pest resistance but it is susceptible to frosts but successfully competes with weeds and smothers them but combines well with legumes.

Carbon 4 Plants

Hyparrhenia rufa, the predominant grass for cattle grazing at the ranch is a Carbon 4 (C4) grass. The C4 grasses grow well under high temperatures. C4 grasses are more efficient in fixing carbon dioxide than other grasses; however, they have a specialized thick-walled parenchyma bundle sheath around each vascular bundle and much smaller portion of more compact thin walled mesophyll tissue than C3 grasses (Wilson 1993). These anatomical characteristics results in plants with less concentration of crude protein and soluble carbohydrates and greater concentration of cell wall components such as cellulose and hemicellulose compared to C3 grasses.

Nutritive Value of C4 Grasses

Forage nutritive value is defined as the chemical composition, digestibility, and nature of digested products of forage (Mott and Moore, 1995) and is often expressed using CP, IVDMD, NDF, ADF and lignin. The nutritive value of C4 grasses can be excellent early in the growing season, but because of their rapid growth and maturity, nutritive value can decrease significantly as the growing season progresses (Coleman et al 2004).The C4 mechanism of photosynthesis allows high Carbon dioxide fixation at relatively low leaf –N concentrations and low concentrations of rubsco (Moore et al 2004), which results in plants with smaller CP concentrations than C3 species. Averaged across a large number of species, CP concentration of C4 grasses ranged from 4 - 6% less than C3 grasses and the occurrence of CP deficiency in livestock fed C4 grasses was greater (Minson, 1990). In addition, high temperature at which C4 plants typically grow also promote lignification and reduce plant tissue and cell wall degradability (Vendramin, 1999).

In general, forage quality of C4 grasses declines with maturity. The decrease in leaf to stem ratio caused by the onset of reproductive stems elongation often decreases Nutritive value. Forage nutritive value is determined according to nutrient concentration, nutrient digestibility, (Mort and Moore 1970). Cell walls (NDF) and their derivatives (ADF) have been used either alone or with other chemical entities to predict both intake and digestibility (Moore et al, 1996).

Carbon 4 Grass Quality

Forage quality is expressed in animal performance thus weight gain, milk production wool production and work under the conditions that 1) animals used to compare forage have potential for production and are uniform among treatments. 2) Forages are available in quantities adequate for maximum intake and 3) no supplemental energy and protein are provided (Moore 1994). Forage quality is a function of Nutritive value and intake (Mertens 2009). Animal production is a function of the daily intake of digestible dry matter and therefore depends on both the quantity of food eaten and the digestibility of the feed (Holmer et al, 1966).

It is known that increasing forage mass, starting from low levels of mass, is associated with greater bite weight and intake that lead to greater animal performance (Sollenberger and Burns ,2000). Likewise, it has been shown that at a similar level of forage mass, increasing forage nutritive value is associated with greater animal performance.

In a continuous stocking method, there are no defined periods of grazing and rest and the grazing period is actually equal to the grazing season. To be sustainable, the system must maintain sufficient herbage mass and herbage accumulation rate at all times to support the number of assigned grazing animals. Under grazing, results in an underestimate of the carrying capacity and product per acre and possibly an overestimate of the product per animal. Overgrazing may greatly reduce the product per animal and per acre. Every effort should be made to attain optimum utilization of the forage (Burns 1973).

In grazing, there is little or no direct control of the feed supply and must resort to other methods for keeping the feed supply in equilibrium with the requirements of the animals and some of the alternatives are 1) To adjust the cattle numbers on a fixed area of land 2) To adjust the size of the pasture to provide the correct amount of herbage for a fixed number of animals. 3) To harvest a portion of the pasture for silage or hay during flush period of growth. 4) To feed supplementary roughage or concentrates during periods of low herbage supply and 5) to defer grazing or to under graze in order to provide forage in those periods of season when production is low. Under grazing, results in an accumulation of forage which is not utilized. Over grazing, results in a lower plane of nutrition for the livestock and frequently injury to the sward. So it is very important to choose a stocking rate which is near optimum for the species or management system (Burns et al 2002).

CHAPTER 3
MATERIALS AND METHODS

Pasture Description

The study was conducted at Diamphwe cattle ranch in Malawi located between coordinates of 14˚25's and 33˚30˚E. Diamphwe cattle ranch is at an altitude of 1,300-1,650 m and receives between 763-1140 mm precipitations annually. Almost 90% of rainfall occurs between November to March with little rain between May and October. The average daily minimum temperature is -2˚C and average maximum temperature of 30˚C (Hodges 1999). Diamphwe cattle ranch is characterized by rolling to flat topography with tropical savanna grassland characterized by short grasses and scattered shrubs and trees. Grass which is predominant is *hyparrhenia rufa* followed by *themenda triandra* and *andropogos.* The soil is deep, well- drained latosols on higher parts of the catena, with poorly drained sand and clay soils in the Lowland. Soil, rainfall and temperature data during the study period have been presented in Table 3-1, 3-2 and 3-3 respectively.

Pasture Selection and Forage Sampling

Diamphwe cattle ranch was selected for forage vegetation sampling and study of forage nutritive value based on its high population of cattle about (four thousand cattle) among all the Malawi government ranches and farms (2010 Malawi Government Livestock Report) and due to its characteristic dry season forage shortages.

A total of eight grazing pastures representative of the entire ranch (four in the Upland and four in the Lowland) were selected randomly and demarcated for the study's forage sampling (4 Upland and 4 Lowland). Forage samples were harvested monthly from three sites per pasture from October 2011 to March 2012.

A total of 144 samples (72 Upland and 72 Lowland) were collected, resulting from 18 samples per pasture (3 samples per month per pasture) and 24 samples per sampling thus 12 samples Upland and 12 samples Lowland each month were harvested from the eight grazing pastures using plastic gloves and plucked to a height of 20cm from the ground to represent the height that was being grazed. Each of the three places in each pasture had 4 points selected at random for forage harvesting. Each of the composite forage samples came from 4 sub samples of the three places. Forage samples were placed in a plastic bag after collection. The samples of the forages were dried in an oven 60˚C for 48 hours and then ground passing through a 4mm screen for digestibility, CP, ADF and NDF and I mm screen for mineral analysis. Eight soil samples were randomly taken from the different pastures using a soil augur once on the onset of the rains and also once in the rainy season to asses soil minerals and pH.

Herbage Mass and Accumulation

Representative samples were clipped to a constant height of 15 cm on monthly basis from October 2011 to March 2012.The cage technique was used in quantifying forage accumulation (growth-senescence). Eight cages 1m x 1m were placed at selected representative sites 4 in the Upland and 4 in the Lowland. Cages were placed at sites that represented the average forage mass of the unclipped grassland on the day of cage placement. Since the forage mass of the grass land was already known from other measurements of forage mass during the experiment. The approximate forage mass to start with was known; therefore forage accumulation was determined every month (Forage mass in the cage after 30 days –average forage mass of the grassland 30 days earlier).

Analysis of Nutrients

Forages were analyzed for CP, NDF, ADF, Digestibility and minerals. Forage DM concentration was determined in a forced air oven at 60˚C for 48 hours. Forage samples for nutritive value were ground in an Udy mill (Udy Corporation, Fort Collins, CO.) to pass a 1-mm screen. Nitrogen concentration was determined using a micro-Kjeldahl method, a modification of the aluminum block digestion technique described by Gallaher et al. (1975). Crude protein was determined by multiplying N concentration by 6.25. Forage NDF and ADF concentrations were determined using the Ankom 200 Fiber Analyzer (Ankom Technology,Macedon, NY) according to Van Soet et al.(1991), and IVTD was determined using the ANKOM (2005) adaptation of Van Soet et al. (1996) in an ANKOM Daisy Incubator and an ANKOM 200 Fiber Analyzer (ANKOM Technology, Macedon, NY).

Statistical Analysis

The data obtained from the study were analyzed using the Glimmix procedure of (SAS institute Inc., Cary, NC, USA, Version 9.2) with Kenward-Rogers approximation to determine the denominator degrees of freedom for the test of fixed effects. Herbage mass, herbage accumulation rate and nutritional composition of pastures was analyzed as a repeated measures and tested for the effects of location (i.e. Upland and lowland), month and location *month, with replication and replication *location as the random effects and replication *month *location as the subject. Repeated measures data were separated using the LSD multiple comparison test if a significant preliminary F-test was detected ($P \leq 0.05$). Significance was set at $P \leq 0.05$, and tendencies if $P > 0.05$ and $\leq$ 0.10. Results are reported according to main effects when interactions were not significant.

Table 3-1. Chemical Composition of Soils from Experimental Site

	Onset of the rains		Deep into the rainy season	
	Upland	Lowland	Upland	Lowland
Soil Ph	4.6	4.6	4.8	5.1
% OM	1.31	3.02	1.19	2.28
% N	0.063	0.1525	0.112	0.06
P (ug/g)	13.56	29.0	12.66	41.60
Ca (ug/g)	5.025	1.805	0.705	2.25
Mg (ug/g)	0.101	0.34	0.118	0.608

Table 3-2. Rainfall Data (mm) During the Experimental Period

October	November	December	January	February	March
8	105	41	229	112	297

Table 3-3. Temperature Date °C, During the Experimental Period

	October	November	December	January	February	March
Morning	18	20	18	18	19	19
Afternoon	31	28	27	24	28	26

CHAPTER 4
RESULTS AND DISCUSSION

Herbage Mass and Accummulation

Herbage Mass

Herbage mass did not differ at $P > 0.05$ in the months of October, November and December in both locations but in January, February and March, herbage mass differed $P < 0.05$ (Table 4-1) with Lowland showing greater herbage mass than the Uplands and herbage mass in both locations in the months of January February and March kept on increasing as the season progressed.

The herbage mass of the Lowland areas ranged from 1975 kg/ha to 6350 kg/ha while Upland ranged from 1738 kg /ha to 5650 kg /ha over the same period (Table 4-1). For the period monitored, Lowlands were greater in herbage mass in the months of January, February and March. The difference in herbage mass between Lowlands and Uplands concurs with the findings of Willms 1988 and Borke et al (2001) for the Boreal mixed wood, which indicate that Upland grasslands produce less herbage mass than Lowlands.

The high level *Hyparrhenia rufa* production from Lowlands highlights their importance for supporting livestock production These results provide further evidence on the importance of Lowlands for providing more herbage mass in January, February and March as Sollenberger and Burns, 2000 observed that increasing forage mass starting from low levels of mass, is associated with greater bite weight and intake that lead to greater animal performance. Likewise it has been shown that at a similar level of forage mass, increasing forage nutritive value is associated with greater animal performance (Burns et al 1989). However this finding must be tempered by the fact that Lowlands represent a relatively small fraction of the land scape within Diamphwe cattle ranch. Lowlands represented an average of 5% of the total landscape within Diamphwe cattle ranch indicating Uplands continue to provide the majority of the total available forage.

Despite their limited area, Lowlands demand special attention because of their importance as a concentrated source of abundant forage for livestock. Both Lowland and Upland exhibited progressive seasonal growth which is important for the ranch but both exhibited greatest growth from the month of January, February and March, which was due to heavy rainfall during this period (Table 3-2).

Greater yields in Lowlands are likely caused by more available water. Although both landscape positions experienced the same rainfall (Table 3-2), Lowlands may receive additional water from adjacent uplands either as overland runoff or through ground water movement (Asamoah et al 2004).

Herbage Accumulation

Herbage mass accumulation differed in December to January at $P < 0.05$ with Lowland showing greater herbage mass accumulation than the Uplands (Table 4-2). The rest of the months did not differ between locations $P > 0.05$.

The lack of significant temporal change in accumulated *hyparrhenia rufa* yield in either Upland or Lowland, suggests *hyparrhenia rufa* regrowth appears to compensate for earlier clipping irrespective of the timing of initial defoliation. According to Mott et al (1992), the rapid refoliation is contributed by the presence of active short meristematic regions remaining on the plant after defoliation. The presence of active meristems on the plant after defoliation allows leaf expansion to result solely from expansion of already formed cells rather than requiring new cell production (Culvenor et al, 1989).

However the high regrowth in December to January for the lowlands may have been enhanced by December drought which affected the whole country (Table 3-2) and this drought favored the Lowlands according to (Bork et al 2001) who found that Lowlands were more likely to respond to precipitation occurring during the previous dormant season because are less dry while uplands rely heavily on seasonal rainfall.

ADF, NDF, IVDMD, CP,

Acid Detergent Fiber (ADF)

Irrespective of location, ADF % increased as the rainy season progressed $P > 0.05$ (Table 4-3). This shows that ADF increases with forage maturity. In both Uplands and Lowlands, the ADF is within the range as recommended in most feedstuff of 5-70% (Van Soest, 1991). ADF is often used to predict digestibility since it is the poorly digested fiber fraction but such predictions are not always accurate as (Van soest, 1991) claims no valid theoretical basis to link ADF to digestion. As ADF increases, digestibility of forage decreases.

Neutral Detergent Fiber (NDF)

In both Uplands and Lowlands, there was a gradual increase in NDF $P > 0.05$ as the season progressed, indicating that NDF increases with maturity of forage (Table 4-4). In both Uplands and Lowlands, NDF is within the recommended range in most feed stuff of 10-80% (Van Soest 1991).

NDF is inversely related to digestibility and intake potential of feed as it predicts the extent of biological degradation which is the process whereby three main groups of rumen microbes namely bacteria, protozoa and fungi carry out most digestion of fiber. Most rumen bacteria attach themselves to feed particles, and fiber digestion will only occur by attached microbes. Fiber causes physical stimulation to the rumen and more protozoa and cellulolytic bacteria are produced which help in breaking down the fiber.

In both Lowlands and Uplands, the range of its NDF is good because it is above the minimum requirement for ruminants according to N.R.C requirement for cattle. Since ruminants need adequate course insoluble fiber for normal rumen function, fiber helps in adequate rumination and cellulose digestion which helps in increasing intake. Fiber also helps to maintain rumen pH and cellulolytic microorganisms that produce high acetate to propionate ratio needed for normal lipid metabolism.

Daily rumination time is directly proportional to coarse NDF intake and related to body size (Robertson et al 1991) and also NDF is better related to intake and gastro intestinal fill than any other measure of fiber (Robertson et al 1991). NDF values are important in ration formulation because they reflect the amount of forage the animal can consume. As NDF % increases, dry matter intake will generally decrease.

Invitro Dry Matter Digestibility (IVDMD)

Uplands had greater IVDMD $P < 0.05$ in October and November as compared to Lowlands while the rest of the months did not differ $P > 0.05$ but the least digestible months was December in both locations, which could be attributed to drought experienced in this month which caused more lignification as forage matures fast to cope with the drought (Table 4-5).

Differences in fiber composition within the months of the study period in both Uplands and Lowlands were largely not reflected in differences in IVDMD. This might be as a result of some contamination with soil during sampling.

In the Lowlands, the IVDMD ranged from 53.88%-65.28% while in the Uplands IVDMD ranged from 53.90%-70.98% all these fall within the recommended range of most feed stuff of 20-80% (Van Soest, 1991).

According to Hanley (1989), due to the nutrients requirement of beef cattle, digestible dry matter must be at least 43-70% to meet maintenance, growth, and lactation requirements during the growing season (Rittenhouse et al 1989).

Crude Protein (CP)

Upland showed greater CP % $P < 0.05$ than the Lowland in the months of October and November but the rest of the months did not differ at $P > 0.05$ (Table 4-6). As Herbage Mass accumulation and maturity increase digestibility and CP decrease. CP decreased as NDF, ADF and Herbage Mass increased so, CP decreases as plant matures (Sollenberger et al 2011).

The simultaneous decline in CP, in Lowlands and Uplands grasslands better describes the varying season long CP dynamics in the Ranch. From October to March, Lowland CP concentration declined from 11.55% to 6.95% while Upland declined from 15.90% to 6.33% representing a total decrease of 40% on Lowlands and 60% on Uplands.

A small decline in CP among the Lowland as compared to Upland grassland as the season progressed may be linked to favorable growth due to abundant soil moisture and plants remaining in a younger more vegetative stage of growth (Irving et al 2003).

Macrominerals

Calcium (Ca)

In both the Lowland and Upland, there was a general simultaneous decline in calcium concentration from October to March P > 0.05 (Table 4-7). This better describes the decline in calcium concentration as forage mature (Sollenberger et al 2010).

Mean calcium levels ranged from 0.295% in March to 0.388% in October in the lowland and 0.298 to 0.359 in the uplands (Table 4-7). These mean calcium levels were sufficiently higher than the recommended levels established by N.R.C 1996 for growing, finishing and early lactation of beef cattle.

Phosphorus (P)

There was no difference in P concentration at P > 0.05 between the locations in November but the rest of the months differed P < 0.05 with Upland showing greater P concentration than the Lowlands mainly in early rainy season and the P concentration decreased as the rainy season progressed (Table 4-8).

Mean P levels ranged from 0.213% to 0.315% in the Lowlands while in the Uplands mean P levels ranged from 0.256% to 0.326%. These mean P levels were sufficiently higher than the recommended levels established by N.R.C 1996 for growing, finishing which is 0.12% to 0.34% and early lactation 0.16% to 0.24%.

It is generally recommended that diets for ruminants should have Ca:P ration of about 1:1 to 2:1 (Khan et al 2006) of which in this study the ratio was in accordance to this requirement. Ruminants can tolerate dietary Ca:P ratio of more than 10:1 without any serious effect provided the P in take are adequate (Ternouth,1990)

Potassium (K)

There were differences in K concentration at $P < 0.05$ in both locations in the month of October, December and February (Table 4-9). During these months, Uplands showed greater concentration of K than the Lowlands, but in both locations there was a general decline in K concentration as the season progressed which was as a result of maturity of plants (Maryland et al 1987)

The range for K levels in the Lowland was 1.25% to 1.72% while in the uplands it was 1.25% to 2.64%. In both instances, the concentration of K was above the recommended levels of 0.6 for growing, finishing and 0.7% for early lactation of beef cattle (N.R.C 1996).

An increase in forage K beyond the requirement but with the tolerable levels is attributed to the fact that young forages generally contain considerably more K than required by grazing livestock (Arthington and Mc Dowell 2005).

Magnesium (Mg)

Regardless of location, Mg concentration in both Uplands and Lowlands decreased as the season progressed, $P > 0.05$ (Table 4-10). The range of Mg concentration in lowlands was 0.98% to 0.215% while in the uplands the range was 0.175% to 0.215%. In both upland and lowland grassland, the Mg levels were within the recommended range of growing, finishing and early lactation of beef cattle of 0.10.and 0.20 respectively (N.R.C 1996).

Sodium (Na)

In February, Na concentration differed, with Lowlands showing greater Na concentration than the Uplands $P < 0.05$ (Table 4-11).

In the Lowland, Na levels ranged from 0.003% to 0.01% while in the uplands, Na levels ranged from 0.004% to 0.009. In both instances, Na concentration was below the recommended for ruminants. The Na requirement for growing and finishing beef cattle is 0.06%-0.08% and lactating cattle is 0.10% (NRC 1996). Due to secretion of salt in milk, even after prolonged severe deficiency Nacl levels secreted in milk remain high (Loosli 1976). The common salt needs of grazing cattle for example can easily be met with mineral mixtures containing 20 to 35% salt and consumed at a rate of 45 grams per head daily.

These findings are in line with the findings of Arthington and Mc Dowell 2005 that tropical forages normally do not contain sufficient quantities of Na to meet the requirements of grazing livestock throughout the year where large losses of water and Na occur in the sweat.

Sulphur (S)

October showed a greater S concentration in the Uplands than Lowlands $P < 0.05$. In the Lowland, mean S levels ranged from 0.069% to 0.115% while in the Upland, S levels ranged from 0.063 to 0.140 (Table 4-12). In both instances, sulfur levels fell below the recommended requirement for beef cattle of 0.15% (N.R.C 1996). Supplementation is needed. This means the forage is deficient in Sulfur during this period. The highest need for sulfur for ruminants is for optimum microbial action. (Arthington and Mc Dowell 2005).

Chlorine (Cl)

The month of October differed in Cl concentration $P < 0.05$ with Upland showing greater Cl concentration than the Lowlands (Table 4-13). As the season progressed, Cl concentration declined an indication that Cl becomes diluted as Herbage mass increases. In the Lowland, Cl levels ranged from 0.308 to 0.760 while in the Upland, Cl levels ranged from 0.305 to 1.040. The Cl requirement for ruminants is generally unknown, but from limited data, the Cl requirement for lactating dairy cows is estimated to be between 0.1% and 0.2% (Fettman et al 1984). From this study, it seems the Cl levels in both Lowland and Upland are beyond the recommended but most animals can tolerate large quantities of dietary salt when adequate supply of water is available Mc Dowell 1992.

Microminerals

Iron (Fe)

Upland differed with Lowland in Fe concentration in the months of January and March $P < 0.05$. Upland showed greater Fe concentration than Lowland and the rest of the months did not differ (Table 4-14). In the Lowland, Iron levels ranged from 187.3 ppm to 289.3 ppm while in the uplands Iron levels ranged from 191.3 ppm to 447.3ppm.In both Upland and Lowland, the Iron levels exceeded the recommended levels required for ruminants and there is no danger for toxicity, because the maximum tolerable level is 1000 ppm. (Arthington and Mc Dowell 2005). Iron deficiency is considered rare for grazing livestock due to generally adequate pasture concentration together with contamination of plants by Iron rich soil. The majority of tropical soils are acidic, resulting in forage levels of Iron generally in excess requirements. In addition, soil consumption will provide substantial quantities of Iron to grazing livestock. Iron supplementation is most wanted when forages contain less than 100 ppm (Arthington and Mc Dowell 2005).

Copper (Cu)

Upland differed with Lowlands in Cu concentration in the months of October, November, December and March $P < 0.05$. Cu concentration was greater in the Upland than in the Lowland (Table 4-15). In both locations, Cu concentration declined as the season progressed. In the Lowland, the mean Cu ranged from 5.25ppm to 7.25 ppm while in the Upland, it ranged from 6.00 to 9.42ppm. Both in the Lowland and Upland, there was a gradual decline in Cu levels in the forages as the season progressed this is in line with Mc Dowell 1996 that forage Cu content decline with forage maturity. In both Upland and Lowland, the pasture forages had lower levels of Cu than the minimum recommended requirement for ruminants for different production purposes (Spears 2003).

Deficiency of Cu in grazing cattle could be further intensified by its reported low bioavailability (Khan 2003). Low forage Cu in this study may have been due to its interaction with other elements in soil. Mc Dowell et al 1993 reported that Cu interacts strongly with trace minerals and macro minerals for absorption by the plants. Fe and Ca are some of the elements that could have had an effect on the absorption of Cu because the concentration of these elements was very high as observed in this study (Tables 4-7 and 4-14). Ca in the form of carbonate precipitates Cu making it unavailable to plants (Khan 2003)

Molybdenum (Mo)

In the months of December, February and March, Mo concentration differed, $P < 0.05$ between Lowlands and Uplands. In these months, Lowlands showed greater, Mo concentration than the Uplands (Table 4-16). This could be attributed to increased soil pH and poorly drained soil in the lowland since for plant uptake of Mo to occur soils should be poorly drained.

In the Lowland grassland, the mean Mo concentration ranged from 1.60 ppm to 3.95 ppm while in the Upland grassland, Mo ppm ranged from 0.95 ppm to 2.05 ppm. In both the Lowland and Upland, the Mo concentration exceeded the recommended requirements for beef cattle of less than 2 ppm but still falls short of being toxic since in both Uplands and Lowland, the Mo concentration is below the toxic levels of 5 ppm however actual requirements of Mo are not established (Arthington and Mc Dowell 2005). No characteristic syndrome of Mo deficiency unrelated to Cu has been recognized and animals perform normally on extremely low dietary levels of Mo. No Mo deficiencies have been reported or identified in grazing ruminants (Arthington and Mc Dowell 2005).

An exact estimate of the Mo requirement is impossible since Cu and S alter Mo metabolism. In both the Lowland and Upland, a conditioned Cu deficiency is not likely because in the Lowland the Cu: Mo ratio are 2:1 in line with Miltimore and Mason (1971) to avoid a conditioned Cu deficiency while in the Upland, the Cu: Mo ratio are above 4:1 as proposed by Allway, (1973) to ensure that the Cu requirement is met. Since S is low in this study, Cu deficiency not a problem.

Zinc (Zn)

In the months of October and March, Zn concentration differed in both locations $P < 0.05$. In October, Upland showed greater Zn concentration which met the recommended requirements for beef cattle while in March, Lowland showed greater Zn concentration than Uplands (Table 4-17).

In the Lowland, the mean concentration of Zn ranged from 18.9 ppm to 23.5 ppm and in the Upland, Zn concentration ranged from 18.0 ppm to 35.0 ppm. In both the Lowland and Upland, the forage is below the recommended requirement for grazing and finishing and for early lactation of beef cattle of 30.0 ppm (NRC, 1996).

Plant maturity has also been reported to affect Zn concentration of forage (Kabata 1992). Low levels of Zn in soils, plants and animal tissues have now been reported throughout many tropical regions of the world. (Mc Dowell 2002). Zn must be present in the diet of all animals and must be supplied almost continuously because animals have only small amounts of readily available Zn stored in the body.

Manganese (Mn)

Concentration of Mn did not differ in both Uplands and Lowlands $P > 0.05$, but Mn concentration declined regardless of location as the season progressed (Table 4-18). In the Lowland, forage mean Mn levels ranged from 94.3 ppm to 261.8 ppm while in the Upland, forage Mn ranged from 69.5 ppm to 219.5 ppm. In both the Upland and Lowland, forage Mn exceeded the recommended requirement for growing and finishing of beef cattle of 20 ppm and early lactation of 40 ppm (N.R.C 1996). Most feeds are adequate in Mn which precludes a need for supplementation (Arthington and Mc Dowell 2005). In the study conducted, the concentration exceeded the requirement for ruminants but animals appear to be highly tolerant of excess dietary Mn. According to N.R.C 1980, maximum dietary tolerable level of Mn for sheep and cattle is 1000 ppm.

Cobalt (Co)

Concentration of Co did not differ in Upland and Lowland $P > 0.05$ regardless of location, Co concentration declined as the rainy season progressed (Table 4-19). In the

Lowland, the mean Co levels ranged from 0.043 ppm to 0.528 ppm while in the Upland forage Co levels ranged from 0.183 ppm to 0.870 ppm. In both the Lowland and Upland, forage met the recommended requirement of 0.1 to 0.25 for beef animals NRC 1996.

Conclusion

A deeper understanding of the Forage Nutritive Value is needed to reduce the risk of failure when raising cattle at Diamphwe Cattle Ranch. Good forage nutrition may help to overcome some of the problems at the ranch. The development of nutrient supplementation strategies suitable to provide the animals with the required nutrients at critical times of the year is necessary.

The results also showed the importance of lowlands for livestock production in the ranch although lowlands constituted only a small fraction of this landscape, they provided greater levels of herbage mass throughout the study period. In order to identify grazing strategies, necessary to maintain long term herbage productivity, and quality, an understanding is required of the dynamics of herbage yield and quality within these complex landscapes so a recommendation of conducting the study throughout the year is necessary so that soundly based nutrient supplementation strategies can be devised.

Table 4-1. Herbage Mass, kg/ha

Month	Lowland	Upland	*P*-value
October	2575^{a}	1738^{a}	0.182
November	2675^{a}	1850^{a}	0.188
December	1975^{a}	1850^{a}	0.840
January	6075^{b}	2750^{ab}	<0.0001
February	6100^{b}	3200^{b}	<0.0001
March	6350^{c}	5650^{c}	0.009

Pooled SEM = 615.1

Trt: $P < 0.0001$; Period: $P < 0.0001$; Trt x Period: $P = 0.004$

^{abc}Means within a column differ; $P < 0.05$

Table 4-2. Herbage Accumulation, kg/ha daily

Month	Lowland	Upland	*P*-value
Oct to Nov	3.8^{a}	4.0^{a}	0.881
Nov to Dec	0.0^{a}	7.0^{a}	0.212
Dec to Jan	146.5^{b}	14.3^{a}	<0.0001
Jan to Feb	34.0^{a}	37.5^{a}	0.938
Feb to March	48.0^{a}	87.8^{b}	0.290

Largest SEM = 30.46

Trt: P =0.186; Period: P = 0.004; Trt x Period: P = 0.002

^{abc}Means within a column differ; $P < 0.05$

Table 4-3. ADF, % of DM

Month	Lowland	Upland	*P*-value
October	34.17[a]	32.67[a]	0.100
November	33.66[a]	34.01[a]	0.691
December	35.21[a]	36.49[b]	0.155
January	35.31[a]	37.09[bc]	0.052
February	38.87[b]	38.41[cd]	0.610
March	39.63[b]	38.90[d]	0.418

Pooled SEM = 0.8828

Trt: P =0.749; Period: $P < 0.0001$; Trt x Period: $P = 0.106$

[abc]Means within a column differ; $P < 0.05$

Table 4-4. NDF, % of DM

Month	Lowland	Upland	*P*-value
October	64.60[a]	62.80[a]	0.062
November	61.85[b]	62.20[a]	0.710
December	64.15[a]	64.75[b]	0.525
January	64.90[a]	65.53[bc]	0.508
February	67.88[c]	66.55[c]	0.165
March	70.13[d]	68.73[d]	0.143

Pooled SEM = 0.935

Trt: P =0.206; Period: P < 0.0001; Trt x Period: P = 0.227

[abc]Means within a column differ; P < 0.05

Table 4-5. In Vitro Dry Matter Digestibility, %

Month	Lowland	Upland	*P*-value
October	62.20^{ac}	70.98^{a}	0.003
November	57.88^{ab}	62.63^{b}	0.094
December	53.88^{b}	53.90^{c}	0.993
January	64.05^{c}	63.25^{b}	0.773
February	65.28^{c}	61.15^{b}	0.143
March	59.45^{a}	62.35^{b}	0.299

Pooled SEM = 2.744

Trt: P =0.190; Period: $P < 0.0001$; Trt x Period: $P = 0.036$

^{abc}Means within a column differ; $P < 0.05$

Table 4-6. Crude Protein, % of DM

Month	Lowland	Upland	*P*-value
October	11.55^{a}	15.90^{a}	<0.0001
November	11.45^{a}	13.03^{b}	0.002
December	8.40^{b}	8.48^{c}	0.876
January	8.68^{b}	8.25^{c}	0.379
February	7.68^{c}	7.23^{d}	0.351
March	6.95^{c}	6.33^{d}	0.198

Pooled SEM = 0.476

Trt: P =0.0007; Period: P < 0.0001; Trt x Period: P < 0.0001

[abc]Means within a column differ; P < 0.05

Table 4-7. Calcium, % of DM

Month	Lowland	Upland	*P*-value
October	0.388[a]	0.359[a]	0.173
November	0.375[a]	0.365[a]	0.542
December	0.375[b]	0.373[a]	0.878
January	0.323[b]	0.355[a]	0.054
February	0.290[c]	0.303[b]	0.446
March	0.295[bc]	0.298[b]	0.878

Pooled SEM = 0.0162

Trt: P =0.871; Period: $P < 0.0001$; Trt x Period: $P = 0.266$

[abc]Means within a column differ; $P < 0.05$

Table 4-8. Phosphorous, % of DM

Month	Lowland	Upland	*P*-value
October	0.255^{a}	0.326^{a}	0.007
November	0.315^{b}	0.300^{ab}	0.471
December	0.255^{a}	0.295^{ab}	0.062
January	0.255^{a}	0.298^{ab}	0.048
February	0.238^{ac}	0.280^{bc}	0.048
March	0.213^{c}	0.258^{c}	0.037

Pooled SEM = 0.0205

Trt: P =0.024; Period: P = 0.0001; Trt x Period: P = 0.082

^{abc}Means within a column differ; $P < 0.05$

Table 4-9. Potassium (K) % of DM

Month	Lowland	Upland	*P*-value
October	1.69[a]	2.64[a]	<0.0001
November	1.72[a]	1.86[b]	0.221
December	1.57[ab]	1.83[bc]	0.035
January	1.62[a]	1.62[cd]	0.983
February	1.37[b]	1.59[d]	0.060
March	1.25[b]	1.25[e]	1.000

Pooled SEM = 0.1425

Trt: $P < 0.0001$; Period: $P < 0.0001$; Trt x Period: $P = 0.0002$

[abc]Means within a column differ; $P < 0.05$

Table 4-10. Magnesium (Mg) % of DM

Month	Lowland	Upland	***P*-**value
October	0.215[a]	0.215[a]	1.000
November	0.208[a]	0.195[ab]	0.334
December	0.200[a]	0.210[ab]	0.439
January	0.195[a]	0.193[ab]	0.846
February	0.195[a]	0.175[b]	0.126
March	0.195[a]	0.193[ab]	0.846

Pooled SEM = 0.0156

Trt: P = 0.404; Period: P = 0.072; Trt x Period: P = 0.658

[abc]Means within a column differ; $P < 0.05$

Table 4-11. Sodium (Na), % of DM

Month	Lowland	Upland	*P*-value
October	0.009^{a}	0.009^{a}	0.731
November	0.006^{b}	0.005^{bc}	0.392
December	0.003^{c}	0.004^{b}	0.667
January	0.005^{b}	0.006^{c}	0.519
February	0.010^{a}	0.006^{bc}	0.001
March	0.009^{a}	0.009^{a}	0.830

Pooled SEM = 0.0014

Trt: $P = 0.315$; Period: $P < 0.0001$; Trt x Period: $P = 0.038$

^{abc}Means within a column differ; $P < 0.05$

Table 4-12. Sulfur (S), % of DM

Month	Lowland	Upland	*P*-value
October	0.093[a]	0.140[a]	<0.0001
November	0.115[b]	0.113[b]	0.716
December	0.085[a]	0.090[c]	0.468
January	0.087[a]	0.088[c]	0.716
February	0.068[c]	0.078[c]	0.151
March	0.060[c]	0.063[d]	0.716

Pooled SEM = 0.0068

Trt: $P = 0.001$; Period: $P < 0.0001$; Trt x Period: $P = 0.001$

[abc]Means within a column differ; $P < 0.05$

Table 4-13. Chlorine, (Cl) % of DM

Month	Lowland	Upland	*P*-value
October	0.463^{a}	1.040^{a}	<0.0001
November	0.760^{b}	0.753^{b}	0.906
December	0.653^{b}	0.693^{b}	0.532
January	0.428^{a}	0.460^{c}	0.611
February	0.345^{ac}	0.330^{d}	0.814
March	0.308^{c}	0.305^{d}	0.969

Pooled SEM = 0.0775

Trt: $P = 0.0005$; Period: $P < 0.0001$; Trt x Period: $P < 0.0001$

^{abc}Means within a column differ; $P < 0.05$

Table 4-14. Fe, ppm

Month	Lowland	Upland	P-value
October	216.8^{a}	213.2^{a}	0.922
November	216.3^{a}	238.8^{ac}	0.434
December	187.3^{a}	191.3^{a}	0.889
January	289.3^{b}	447.3^{b}	<0.0001
February	270.8^{b}	293.8^{c}	0.424
March	201.5^{a}	288.3^{c}	0.005

Pooled SEM = 35.96

Trt: $P = 0.024$; Period: $P < 0.0001$; Trt x Period: $P = 0.003$

^{abc}Means within a column differ; $P < 0.05$

Table 4-15. Copper (Cu), ppm

Month	Lowland	Upland	*P*-value
October	7.25[a]	9.42[a]	0.001
November	7.00[a]	8.00[b]	0.027
December	5.25[b]	6.00[c]	0.092
January	6.50[a]	6.50[c]	1.000
February	6.67[a]	6.00[c]	0.165
March	5.75[b]	7.75[b]	<0.0001

Pooled SEM = 0.469

Trt: $P < 0.0001$; Period: $P < 0.0001$; Trt x Period: $P = 0.001$

[abc]Means within a column differ; $P < 0.05$

Table 4-16. Molybdenum (Mo), ppm

Month	Lowland	Upland	*P*-value
October	1.60^{a}	1.46^{ab}	0.801
November	2.25^{a}	2.05^{a}	0.675
December	2.25^{a}	0.95^{b}	0.011
January	2.10^{a}	1.50^{ab}	0.215
February	3.63^{b}	1.05^{b}	<0.0001
March	3.95^{b}	2.03^{a}	0.001

Pooled SEM = 0.561

Trt: $P = 0.010$; Period: $P = 0.0002$; Trt x Period: $P = 0.001$

^{abc}Means within a column differ; $P < 0.05$

Table 4-17. Zinc (Zn), ppm

Month	Lowland	Upland	*P*-value
October	23.3[a]	35.0[a]	<0.0001
November	23.5[a]	22.0[b]	0.287
December	18.8[b]	19.8[b]	0.476
January	22.3[a]	21.5[b]	0.592
February	19.0[b]	18.5[c]	0.721
March	22.3[a]	18.0[c]	0.004

Pooled SEM = 1.70

Trt: P = 0.113; Period: P < 0.0001; Trt x Period: P < 0.0001

[abc]Means within a column differ; $P < 0.05$

Table 4-18. Manganese (Mn), % of DM

Month	Lowland	Upland	*P*-value
October	243.8^{a}	219.5^{a}	0.603
November	261.8^{a}	159.0^{ab}	0.011
December	246.3^{a}	135.3^{b}	0.007
January	162.8^{b}	150.0^{ab}	0.734
February	110.5^{bc}	109.3^{bc}	0.973
March	94.3^{c}	69.5^{c}	0.510

Pooled SEM = 45.99

Trt: P = 0.101; Period: P < 0.0001; Trt x Period: P = 0.131

^{abc}Means within a column differ; P < 0.05

Table 4-19. Cobalt, ppm

Month	Lowland	Upland	*P*-value
October	0.528^{a}	0.500^{ab}	0.907
November	0.490^{a}	0.870^{a}	0.053
December	0.363^{ab}	0.365^{b}	0.990
January	0.263^{ab}	0.295^{b}	0.865
February	0.045^{b}	0.253^{b}	0.281
March	0.043^{b}	0.183^{b}	0.465

Pooled SEM = 0.2362

Trt: P = 0.194; Period: P = 0.002; Trt x Period: P = 0.681

^{abc}Means within a column differ; $P < 0.05$

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BIOGRAPHICAL SKETCH

Felix Goodson Makondi was born in Thyolo, Malawi to a police officer; Felix attended several primary schools in Thyolo, Blantyre, Zomba, Mangochi and Lilongwe Districts and secondary education at Saint Patricks in Blantyre district. Thereafter, he graduated from The University of Malawi, Bunda College of Agriculture with a Bachelor of Science degree in the field of animal sciences in 2002. Upon graduation, he got a job in the Ministry of Agriculture as a Livestock Development Officer with the first posting at Blantyre Agricultural Development Division and later in 2005 was posted to Diamphwe Cattle Ranch. In 2010, Felix moved to Florida, United States of America to pursue his master's degree in animal sciences at University of Florida with financial support from United States Agency for International Development (USAID) under the supervision of Dr. John Arthington. His major focus has been on forage nutrition evaluation at a Beef Cattle Ranch.