Grazing and feeding strategies for improving small-scale agro-pastoral livestock production in Tanzania

Beite- og fôringsstrategier for å forbedre småskala agro-pastoral husdyrproduksjon i Tanzania

Philosophiae Doctor (PhD) Thesis 2014

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Thesis number 2014:59

ISSN: 1894:6402

ISBN: 978-82-575-1221-7

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ACKNOWLEDGEMENTS

I would like to express my sincere thanks to the Norwegian State Education Fund (Lånekassen) for financial support and the Norwegian University of Life Sciences for giving me the opportunity to pursue my PhD studies. I am grateful to the Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains (EPINAV) programme for financially supporting the fieldwork.

I would like to express my sincere gratitude to my main supervisor Prof. Lars Olav Eik at the Norwegian University of Life Sciences, Department of International Environment and Development Studies, for his continuous encouragement, moral support and close supervision. I am also grateful to my co-supervisors; Prof. Øystein Holand, Prof. Tormod Ådnoy, Prof. Ephraim Mtengeti and Dr. Daniel Mushi for their support and valuable comments throughout the course of my study. Indeed, I am very grateful to Prof. Tormod Ådnoy for his excellent guidance in statistical analysis. Lucy Robertson was very helpful in critically and rigorously reviewing papers that helped me a lot during my publication.

I am most grateful to Prof Anna Haug at the Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, for her support regarding knowledge of animal nutrition components and to Mr. Dominic A. N. Alute and Gedalia M. Muffui in the Department of Animal Science and Production, SUA for good collaboration and assistance in the laboratory work. In the various field work studies, the assistance by Dr. Crispinus Rubanza, Dr. John Safari, Dr. Angello Mwilawa, Mr. Protas Mihayo, Pastory Mwesigwa, Nyenye Hussein, Abeli Kijoji, Alfonce Mnyaw, Haji Ahmadi, Miss Anna Shao, Magdalena Gabriel and Irene Lyamuya is highly acknowledged.

I would like to acknowledge the Natural Resources and Agro-forestry Centre (NAFRAC) and the Tanzania Traditional Energy Development and Environmental Organization (TaTEDO) in Shinyanga for providing transport support and research assistants during the period of data collection. The management of the Haydom Farm and Development Ltd is also acknowledged for providing experimental animals and feedlot structures for handling animals. The administration of the University of Fort Hare, South Africa is very much acknowledged for hosting me during the short course on African ecology and renewable resources management. Specific thanks to Prof. Peter Lent and Prof. Voster Muchenje for imparting to me their great field inventory skills.

I wish to thank my fellow PhD students at NMBU: Mulubrhan Gebremikael, Devota Mwaseba, Zabron Nziku and Beatrice Kilima for their encouragement and good cooperation. I appreciate their kindness and good companionship that contributed to reduce my loneliness. Finally, I wish to thank my family for their encouragement, support and inspiration throughout my study. Special thanks to my dear mammy and daddy, Mr. and Mrs. Selemani, who understood my academic endeavors and encouraged me throughout my studies. I express my deepest gratitude to my lovely wife, Halima Jumanne Tsuhulay, for her patience and confidence in carrying out the responsibility of raising our children in my absence. Thank you for being so patient with me, you really deserve congratulation.

ABBREVIATIONS

ADF	Acid Detergent Fiber
ADG	Average daily gain
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BCS	Body condition scores
BD	Bulk density
CIDA	Canadian International Development Agency
CL	Carcass length
CP	Crude protein
DASP	Department of Animal Science and Production
DM	Dry matter
EE	Ether Extract
EPINAV	Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains
FAO	Food and Agriculture Organization
GDP	Gross Domestic Products
GLM	General linear model
GM	Grazing management
GPS	Global positioning system
HASHI	Hifadhi Ardhi Shinyanga
HL	Hind legs
HT	Height of Tree
INVDMD	*In vitro* dry matter digestibility
INVOMD	*In vitro* organic matter digestibility
LBM	Lowest browsable materials
LD	*Longissimus dorsi*
NAFCO	National Agriculture and Food Cooperation
NAFRAC	Natural Resources and Agro-forestry Centre
NBS	National Bureau of Statistic
NDF	Neutral detergent fiber
NGOS	Non-governmental organizations
NP	Natural pasture
PANTIL	Programme for Agricultural and Natural Resources Transformation for Improved livelihoods
PCQ	Point-Centered Quarter
PS	Pasture plus Supplementation
SAS	Statistical Analysis Software
SE	Standard error
SF	Stall feeding
SH	Sward height
SUA	Sokoine University of Agriculture
TaTEDO	Tanzania Traditional Energy Development and Environmental Organization
NMBU	Norwegian University of Life Sciences
URT	United Republic of Tanzania
VFA	Volatile Fatty Acid
WBSF	Warner-Bratzler Shear Force

ABSTRACT

Tanzania is highly populated with domesticated ruminant livestock, with about 3.9 % gross domestic product (GDP) growth rate. More than 70 % of the ruminant livestock population is in the north-western and central parts of the country: Shinyanga, Simiyu, Mwanza, and Manyara. Ruminant production depends largely on communal rangelands that are constrained by scarcity of forage, especially during the dry season. Growth in human and livestock populations in Tanzania has increased the pressure on grazing land and overwhelmed traditional grazing practices. Transformation of traditional land use systems to official land use policies has resulted in an expansion in cultivation and wildlife conservation areas, and thus greater pressure on grazing land. The existing grazing systems and feeding strategies were studied in order to provide information that could be used to improve agro-pastoral practices.

The study encompasses four papers. In paper I, the effect of a deferred grazing system on rangeland vegetation in the north-western semi-arid regions of Tanzania was assessed using aboveground biomass, vegetation cover, and species composition as indicators of range condition. In paper II, the effects of seasonal variation in quality and quantity of pasture and management of exclosures (*ngitili*) on grazing behavior of cattle and goats were assessed. In paper III, the effect of natural pasture versus concentrate supplementation on growth performance and foraging behavior of Zebu cattle was tested. The fourth component of the study (paper IV) evaluated the effect of natural pasture versus concentrate feeding systems on carcass characteristics and meat quality of Tanzania Zebu steers.

In paper I, five grazing systems (old private *ngitili*, young private *ngitili*, old communal *ngitili*, young communal *ngitili*, and continuously grazed land) were compared in terms of aboveground herbaceous biomass, vegetation cover and species composition. The herbaceous vegetation cover was significantly higher in all exclosures than on continuously grazed land, but the aboveground herbaceous biomass was only significantly higher in old private *ngitili* than in the other grazing systems. Neither herbaceous species diversity nor woody density were significantly dependent on grazing regimes. In paper II, the quality (i. e. crude protein content, neutral detergent fiber, and *in vitro* organic matter digestibility) of five important forage species and quantity of forages (i. e. aboveground biomass and bulk density) were found to be significantly better in the rainy season than in the dry season. This was also evident from the foraging habits of cattle and goats, as both

spent considerably more time walking around searching for high quality forage during the dry season. Similarly, the reduction in quantity of forage in the communal *ngitili*, as compared with private *ngitili*, had a marked effect on the foraging behavior of goats, but had no significant effect on the feeding behavior of cattle. In experiment three (Paper III), the average daily gain (ADG) was significantly higher for cattle grazing on natural pasture supplemented with concentrate (PS) than those grazing on natural pasture alone (NP). This was also evident from grazing behavior. Animals on PS were found to spend more time idling on natural pasture than those on NP. The last experiment (paper IV) revealed that Zebu cattle fed on wheat straw as a basal diet and supplemented with locally available concentrate mixture demonstrated significantly higher values for ADG, dressing percentage, and marbling scores than pasture-grazed cattle. However, post mortem carcass pH, meat tenderness, meat chemical composition (moisture contents, dry matter, ash, ether extract, and crude protein) and color was not found to be dependent on concentrate supplementation.

It is conclude that: the deferred grazing system (*ngitili*) is an important coping strategy that enables Sukuma agro-pastoral communities to alleviate the shortage of forage in the dry season. However, use of *ngitili* appears to be of limited effect for the restoration of severely degraded communal rangelands in terms of aboveground herbaceous biomass, vegetation cover, and species composition. Stocking animals in mixed herd (cattle and goats) is also beneficial due to their varying foraging habits, resulted in the resource partitioning between cattle and goats. However dietary overlap was noted during acute shortage of forage in the dry season. Thus, concentrate supplementation is of environmental merit because resultant changes in the grazing behavior of steers reduce the defoliation pressures on vegetation on pastureland. Indeed, strategic supplementation of Zebu steers with locally made concentrate mixture has a positive effect on growth performance, carcass characteristics, and meat quality.

For further improvement of agro-pastoral livestock production in Tanzania, It is recommended that: institutions that manage communal rangelands be reorganized in order to improve agro-pastoral livestock production. Both formal and informal rules and codes of conduct that regulate rights of common pool resource should be clearly defined. Decision-making powers be participatory and the benefits accrued from common resources be shared equally. Locally available and affordable concentrate supplementation should be used to enhance ruminant livestock productivity and reduce degradation of rangeland vegetation. Implementation of a well planned rotational grazing system that offers appropriate time for vegetation recovery need further investigation. Moreover, other feeding strategies such as use of crop residues treated with urea and quicklime and supplementation with fodder tree leaves need to be considered.

SAMMENDRAG

Tanzania har Afrikas tredje storste husdyrbestand etter Sudan og Etiopia. Mer enn 70 % av drovtyggerbestanden befinner seg i nord-vest og sentrale deler av landet: Shinyanga, Simiyu, Mwanza og Manyara. Husdyrbestanden i landet er stor, men bidraget fra husdyr til okningen i bruttonasjonalproduktet (BNP) er mindre enn fem prosent. Drovtyggerproduksjonen er i stor grad avhengig av felles beiteområder med begrenset fôrtilgang, spesielt i torkeperioden. Økning i menneske- og husdyrbestanden i Tanzania har medfort et okt beitepress på beiteområdene og tradisjonell beitepraksis gir ikke lenger tilstrekkelig beitevern. Oppdyrking av områder tradisjonelt brukt til beiting og utvida viltreservat i samsvar med offentlige planer har okt presset på beiteområdene. I denne oppgaven blir eksisterende beitesystemer og fôringsstrategier studert med mål om å kunne forbedre beitepraksisen innen husdyrbruk.

Studien består av fire artikler. I artikkel I så en på effekten av å utsette beiting på utmarksvegetasjonen. Dette ble gjort på steppen nord-vest i Tanzania. Biomasse over bakkenivå, dekningsgrad av vegetasjon og artssammensetning ble brukt som indikatorer på tilstanden til beiteområdet. I artikkel II ble effektene av sesongvariasjoner i kvalitet og kvantitet på beiteatferd hos geit og storfe undersokt for ulik forvaltning av avsperrede beiteområder (*ngitili*). I artikkel III ble effekten av kraftfôrtilskudd og naturlig beite på vekstytelse og beiteatferd hos Zebu testet. Den fjerde studien (artikkel IV) evaluerte effekten av naturlig beite kontra kraftfôrtilskudd på slakte- og kjottkvaliteten hos tanzanianske zebukastrater.

I artikkel I ble fem beitesystemer (gamle private *ngitili*, nye private *ngitili*, gamle felles *ngitili*, nye felles *ngitili* og kontinuerlig beitede områder) sammenlignet. Biomasse over bakkenivå, vegetasjonsdekket og artssammensetning ble målt. Vegetasjonsdekket av gras og urter var signifikant hoyere i alle beiteområdene sammenlignet med i de kontinuerlig beitede områdene, men biomassen bestående av gras og urter var bare signifikant hoyere i gamle private *ngitili*. Det ble funnet at hverken mangfoldet av gras og urter eller tettheten av trær var signifikant avhengig av beitesystemet. I artikkel II ble kvaliteten (dvs. råproteininnhold, NDF og *in vitro* fordoyelighet av organisk materiale) av fem viktige förtyper og mengden av för (dvs. biomasse over bakkenivå og massetetthet) var signifikant bedre i regntiden enn i torkeperioden. Dette kom også fram av föringsatferden til storfe og geit siden begge brukte betydelig mer tid på forflytning i torkeperioden for å kunne finne för av god kvalitet. Tilsvarende hadde nedgangen av förmengden i felles *ngitili* sammenlignet med private *ngitili* markant effekt på föringsatferden hos geit, men ingen signifikant effekt på föringsatferden hos storfe. I forsok III ble det vist at gjennomsnittlig daglig tilvekst (ADG) var signifikant hoyere hos storfe som gikk på naturlig beite med tilgang på kraftför (PS) enn de som gikk på naturlig beite uten tilgang på kraftför (NP). Dette syntes også i beiteatferden: Dyr i PS var mer uvirksomme på naturlig beite enn de som gikk i NP-gruppa. Det siste forsoket (artikkel IV) viste at zebu som fikk hvetehalm som primærnæring og ble supplert med lokale tilgjengelige kraftförtyper hadde signifikant hoyere ADG, marmoreringsscore og slakteprosent enn de som bare gikk på beite. Kjottets morhet, pH i slaktet, kjemisk sammensetning (vanninnhold, TS, aske, EE og råprotein) og farge kunne ikke sies å være avhengig av kraftförtillegg.

Det konkluderer at: Det ble funnet at utsatt beiting (*ngitili*) var en viktig mestringsstrategi som gjorde at Sukuma-landbrukssamfunn kunne minske mangelen på för i torkeperioden. Det ser ut til at *ngitili* har liten effekt når en vil bygge opp et sterkt forringet beitelandskap målt som biomasse av urter/gras over bakkenivå, vegetasjonsdekke og artssammensetning. En buskap med flere arter (storfe og geit) ble funnet å være fordelaktig på grunn av forskjellig beiteatferd. Ulik resursutnytting for storfe og geiter var tydelig, men under akutt mangel på för i torkeperioden var det konkurranse om noen beiteplanter. Tilleggsföring av zebu med lokalprodusert kraftför hadde en positiv effekt på tilveksten, slakte- og kjottkvalitet. Endringer i beiteatferden hos kastrater som ble tilleggsföret ga en miljofortjeneste i form av redusert press på bladverket i beiteområdene.

For ytterligere forbedringer av husdyrproduksjonen i Tanzania det anbefales at: institusjonene som administrer felles beiteområder bor omorganiseres. Både formelle og uformelle regler og etiske retningslinjer for bruk av felles ressurser bor bli klart definert. De som har nytte av forvaltningen bor gis myndighet i beslutninger og nytte av felles ressurser bor deles likt. Et velorganisert rotasjonssystem som kan bidra til at beitene får nok tid til å hente seg inn bor undersokes. Det anbefales bruk av lokalt og billig kraftför for å oke produksjonen hos drovtyggere og redusere forringelse av beitevegetasjonen. Endrede föringsstrategier, som bruk av avlingsbiprodukt og supplering med bladverk fra trær som kan brukes som för, er også å anbefale.

LIST OF PAPERS

This thesis is based on the following papers that will be referred to in the text

I. Ismail Saidi Selemani, Lars Olav Eik, Øystein Holand· Tormod Ådnoy, Ephraim Mtengeti, Daniel Mushi. The effect of a deferred grazing system on rangeland vegetation in a north-western, semi-arid region of Tanzania. Published in *African Journal of Range and Forage Science, 2013; 01 (58): 1-8.*

II. Ismail Saidi Selemani, Lars Olav Eik, Øystein Holand· Tormod Ådnoy, Ephraim Mtengeti, Daniel Mushi. Variation in quantity and quality of native forages and grazing behavior of cattle and goats in Tanzania. Published in *Livestock Science, 2013, 157: 173-183.*

III. Ismail Saidi Selemani, Lars Olav Eik, Øystein Holand· Tormod Ådnoy, Ephraim Mtengeti, Daniel Mushi. Concentrate supplementation: Effects on growth performance and behavioral activities of cattle grazed on natural pasture (*manuscript*).

IV. Ismail Saidi Selemani, Lars Olav Eik, Øystein Holand· Tormod Ådnoy, Ephraim Mtengeti, Daniel Mushi, Sorheim Oddvin. Feeding Strategies for Improved Beef Productivity and Reduced GHG Emissions in Tanzania: Effect of Type of Finish-feeding on Carcass Yield and Meat Quality of Zebu Steers. In: Rattan Lal, Bal Ram Singh, Dismas L. Mwaseba, David Kraybill, David Hansen, Lars Eik, Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa, *Springer (forthcoming).*

1. INTRODUCTION

1.1 Feed resources for livestock production

The major livestock production systems in Africa are pastoral and agro-pastoral, and occur mainly in the arid and semi-arid regions. About two-thirds of sub-Saharan Africa is covered with arid or semi-arid lands where income for pastoralists and agro-pastoralists is largely derived from livestock production (Homewood 2004). However, livestock production in these regions is threatened by scarcity of pasture as a result of change in land use due to an expanding human population (Abule et al. 2005). Uncontrolled grazing from large livestock populations and encroachment of rangelands by other land uses, have also contributed to the degradation of rangelands (Kassahun et al. 2008; Vetter 2005).

More than 90 % of the livestock sector in Tanzania belongs to small-scale pastoralists and agro-pastoralists, of whom most (over 70 %) live in semi-arid communal rangelands (Mwilawa et al. 2008). Tanzania has about 21.3 million cattle, 15.1 million goats and 5.7 million sheep (NBS 2012). The contribution of livestock to GDP growth rate was only 3.9 % in 2011 (URT 2011). Ruminant livestock production in the country largely depends on semi-arid rangelands, and these are constrained by forage scarcity, especially during the dry season. Forages from natural pasture are generally of low nutritive value and livestock are frequently exposed to prolonged periods of under-nutrition that impairs their productivity (Kakengi et al. 2001). Mtengeti et al. (2008) attributed the low productivity of the livestock sub-sector in Tanzania to the poor nutritive value of feed and the lack of proper feeding plans. According to Mushi et al (2009), production of poor quality meat in Tanzania is associated with poor nutrition as many animals are mainly raised on poor quality range pastures.

The decline in availability and quality of forage from natural pasture in the dry season forces livestock keepers to feed their animals with available crop residues, such as maize stover and wheat straw. Although crop residues are generally plentiful, they are characterized by low crude protein (CP) levels, ranging from 3 to 4 % and high crude fiber content of 35 to 48 % (Letty & Alcock 2013; Mtengeti et al. 2008). Despite the numerous scientific works that recommend treatment of crop residues with chemicals to enhance their digestibility (Laswai et al. 2007; Mgheni et al. 1993; Mtengeti et al. 2006; Safari et al. 2011b), few of these technologies have been adopted in Tanzania. The synthesis from the FAO (Owen et al. 2012), states that the technologies for improvement of crop residues by chemicals have not been adopted in developing countries, particularly at the small-scale farmer level. One of the challenges for improving the nutritive value of crop residues through chemical treatment is the poor adoption of new innovations by small-scale agro-pastoralists. Most pastoralists and agro-pastoralists in Tanzania are small-scale farmers and the cost of necessary chemicals presents a significant barrier to adoption of these technologies. Failure to improve crop residues through chemical treatment could also be due to the laborious treatment process and the risk of toxicity to animals consuming improperly treated crop residues.

1.2 Deferred grazing system

Pastoralists and agro-pastoralists in Tanzania, like many other pastoralists in Africa such as the Himba in Nambia and Borana in Ethiopia (Aerts et al. 2009), have traditional coping strategies, in which some of their grazing lands are temporarily protected from use and are used as deferred feeds at the peak of the dry season when forage is scarce. These traditional reserved pastures ("*ngitili*" for the Sukuma) have been used for many years among pastoral and agro-pastoral communities to provide dry season feed for ruminant livestock (Mwilawa et al. 2008). However, in the 1970s, the Villagization Program in Tanzania forced the Sukuma pastoralists to move to new areas and thus abandon their indigenous traditional *ngitili* practice. The re-location of pastoralists to newly created settlements disrupted this traditional forage conservation practice (*ngitili*) and made adaptation to new ecological conditions more difficult. However, this indigenous silvo-pastoral technology was revived in the early 1980s, by the Shinyanga Soil Conservation Programme (known as "HASHI" project in Swahili), following the acute shortage of forage in the north-western regions of Tanzania (Barrow & Mlenge 2003).

Severe losses of vegetation in the north-western regions of Tanzania dates back to the colonial era when it was associated with vegetation clearance program for the purpose of eradicating tsetse flies, and hence trypanosomiasis in 1920s (Barrow & Mlenge 2003). This program was environmentally catastrophic as it led to loss of vegetation in vast areas (Pye-Smith 2010). Furthermore, loss of vegetation in these regions has also been associated with increases in the number of livestock and erratic rainfall (Kamwenda 2002). The Sukuma pastoralists invested heavily in livestock production because it provided a relatively high economic return and could be used as a contingency buffer for future emergencies (Dercon 1998). Expansion of crop production due to a rapid increase in the human population has required conversion of grazing lands to crop lands (Pye-Smith 2010), subsequently threatening rangeland resources. Although *ngitili* have been viewed as an important instrument for restoration of degraded rangelands and alleviation of forage shortage, especially in the dry season, this strategy has not been previously evaluated. The effectiveness of *ngitili* in restoration of livestock forage, in terms of biomass production, vegetation cover, vegetation composition and density, has not been quantified. Thus, the overall validity of *ngitili* as an effective *silvopastoral* system, and an important coping strategy remains unknown (Kamwenda 2002).

1.3 Supplementation strategies

Livestock production during the dry season in Tanzania is limited by the low nutritive values of natural pasture. According to Rubanza et al. (2007) the CP content of standing hay forage in preserved grazing lands (i.e. deferred feeds) ranges between 30 to 50 g/kg dry matter (DM). Poor productivity performance of livestock in the dry season has been attributed to the decline in quality of forage (Kanuya et al. 2006). In Manyara region wheat is one of the important commercial crops yielding substantial quantities of wheat straw (132,000 tonnes per annum) that can be used as potential sources of forage in the dry season (Viggo 2008). From 1968, more than 40,000 ha of productive grazing land in the Hanang district within Manyara region were declared by the government to be used by the parastatal National Agriculture and Food Cooperation (NAFCO) for wheat production (Lane 1994).

Despite the plentiful supply of wheat straw in the Manyara region, its utilization by livestock ruminants is limited by the high levels of lignocellulose compounds. According to Klinke et al. (2002), lignocellulose is a major component of wheat straw, and is comprised of cellulose (35-40 %), and hemicellulose (20-30 %), in close association with lignin (8-15 %). The closed compact structure of lignocellulose reduces the fermentation process in ruminants. In order to sustain the livelihood of pastoral communities in the face of diminishing grazing land, improved utilization of available crop residues is essential. Pre-treatment of wheat straw with chemicals opens up the closed structure of lignocellulose, enabling the soluble hemicellulose and cellulose fraction to become available for enzymatic hydrolysis and microbial fermentation. A considerable body of research has focused on improving the digestibility of wheat straw cell walls through chemical and mechanical pre-treatment (Mahr-un-Nisa et al. 2004; Rodrigues et al. 2008; Sun et al. 2005; Wang et al. 2004). However, chemicals such as sodium hydroxide, chlorine, ammonia and hydrogen peroxide are expensive for small-scale agro-pastoralists.

Supplementation with energy and protein-rich concentrates could improve livestock production in terms of milk yield and high quality meat production. Raising animals on concentrate based-diets generally results in high average daily gain (ADG) and high quality meat (Priolo et al. 2001). However, commercial concentrates are often expensive and beyond the economic reach of small-scale agro-pastoralists (Kakengi et al. 2001). Although supplementation with fodder from forage trees has been found to be economically effective and more efficient at improving the utilization of poor quality fibrous feeds (Maasdorpa et al. 1999; Patra et al. 2003), the practice is not very widespread in Tanzania (Ndemanisho et al. 1998).

Strategic supplementation with high-energy rich concentrate feeds improves the rumen efficiency in digesting poor quality roughage, such as crop residues (Wanapat 2000). According to Plaizier et al. (1999), supplementation of dairy cows in Tanzania with urea-molasses block improved the utilization of poor quality hay and subsequently increased their milk yield. Evidence suggests that utilization of wheat straw can be improved by supplementation with high energy-rich feeds that supply sufficient fermentable nitrogen, carbohydrates and micronutrients (Khandaker et al. 1998).

1.4 Feeding and grazing behavior of ruminant livestock

The quality and quantity of forage from natural pasture in Tanzania are mainly affected by season. Seasonal fluctuations in both quality and quantity affect the feeding preferences of the animals and subsequently affect their growth performance (Safari et al. 2011a). The physical structure and chemical composition of these forages change considerably depending on the season and grazing management. In the dry season, forage quality and availability in many parts of the country are generally insufficient for livestock grazing and animals often have inadequate intake of necessary nutrients (Mtengeti et al. 2008). Despite broad scope of knowledge on the grazing behavior of ruminant livestock, there is limited information on the influence of the physical structure and biochemical composition of forage on intake and dietary choices (Griffiths et al. 2003).

Knowledge of the grazing behavior of free-ranging ruminant livestock plays a key role in understanding how different animal species utilize their rangeland resources. In the free-ranging grazing system, factors such as quality and quantity of forage ingested, time spent grazing, and the influence of herdsman may all affect the productivity of grazing animals. Efficient utilization of forage resources and control of the animal impact on rangeland vegetation, requires an in-depth knowledge of those factors that determine feeding behavior and dietary choices (Baumont et al. 2000). Attempts to improve ruminant livestock productivity are always compromised by failure to understand the actual relationships between diet selection and the quality and availability of forage (Ngwa et al. 2000).

2. AIM OF THE STUDY

The overall goal of this study was to evaluate the existing traditional livestock grazing systems and feeding strategies in Tanzania in order to provide a basis for improving productivity of small-scale agro-pastoral production systems. In order to achieve this, the following objectives were addressed;

i. To assess the effect of a deferred grazing system on rangeland vegetation in a north-western, semi-arid region of Tanzania (Paper I).
ii. To quantify the influence of seasonal variations in the quantity and quality of native forages on the grazing behavior of cattle and goats in the north-western regions of Tanzania (Paper II).
iii. To evaluate the effects of concentrate supplementation on growth performance and foraging behavior of Zebu cattle (Paper III).
iv. To assess the effect of concentrate versus natural pasture feeding systems on carcass characteristics and meat quality of Tanzanian Zebu steers (Paper IV).

3. MATERIALS AND METHODS

3.1 Description of study areas

The study was carried out in three districts in the northern and western parts of Tanzania: Meatu in Simiyu region, Shinyanga rural district in Shinyanga region, and Hanang district in Manyara region (Figure 1). All study areas have a semi-arid climate, with a mean annual rainfall ranging from 400 to 800 mm. In the Shinyanga and Simiyu regions, the rainfall is generally unimodal and falls from November to April, but variation in rainfall patterns and quantity is large (Wiskerke 2008). The rainfall is rather unreliable, and these regions often experience a long dry season from May to November. Historically, the Simiyu region was part of Shinyanga region, before it was officially gazetted as an administrative region in 2012. These regions were covered by miombo woodlands toward the west (Shinyanga) and acacia savannah towards the east (Simiyu), however, in 1920s, the regions experienced severe vegetation losses due to the colonial anti-tsetse program (Barrow & Shah 2011). The Shinyanga and Simiyu regions are home to the Sukuma people, who are traditionally agro-pastoralists. These two regions have by far the largest livestock population in the country, with 3.6 million cattle, 1.9 million goats and 0.7 million sheep (NBS 2012).

In the Hanang district, the climate is semi-arid with two rainy seasons; short rain and long rain. Short rain generally falls from November to early December, while the long rain usually starts from mid-March to May. As in the Shinyanga and Simiyu regions, the rainfall pattern in the Manyara region is also unreliable, and the region experiences a long dry season. The vegetation in Hanang district is mainly wooded grassland dominated by acacia species. The district is inhabited by the Iraqw and the Barabaig people (Sieff 1999). Most of the Iraqw are subsistence farmers, with maize as the staple crop while the Barabaig are agro-pastoralists with cattle and goats as their major livestock species (Winkler et al. 2010). The East African short-horn Zebu cattle (*Bos indicus*) and the Small East African (SEA) goats are the main breeds kept in this area (Sieff 1997). The Manyara region has about 1.6 million cattle and 1.5 million goats (NBS 2012).

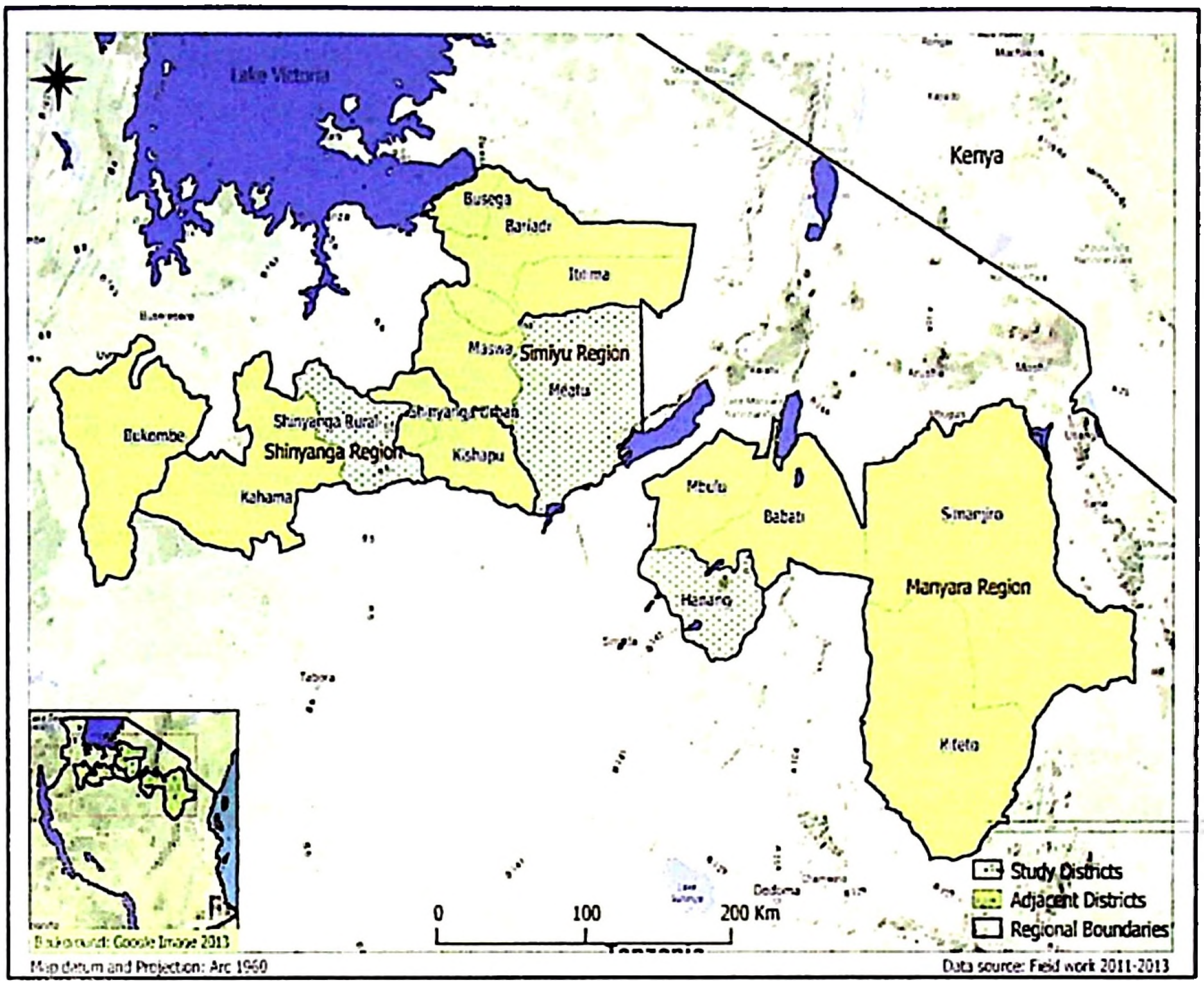

Figure 1: The study areas are situated in the north and north-west regions of Tanzania.

3.2 Sampling procedure

Study I was carried out in Meatu and Shinyanga rural districts (Figure 1) from October to November 2011. The study was based on traditionally deferred grazing areas (*ngitili*) that have been seasonally rested for more than ten years (old *ngitili*) and for ten years and below (young *ngitili*). Five grazing practices (old private *ngitili*, young private *ngitili*, old communal *ngitili*, young communal *ngitili* and continuously grazed lands) were compared for aboveground biomass production, herbaceous vegetation cover, species composition, and structure of woody species. All five grazing practices were investigated in 12 designed sub-plots (two for each old and young *ngitili* and four for continuously grazed lands). A pre-calibrated disc pasture meter was used to estimate the aboveground herbaceous biomass of selected sub-plots. Calibration was done by clipping fifty samples of herbaceous vegetation from five different sub-plots and measuring the aboveground herbaceous biomass under the disc in relation to the height of the aluminum meter ruler. The calibration equation was obtained by plotting the aboveground biomass measured against the height of the aluminum ruler. Thereafter, the disc pasture meter was released at 8 m intervals along two established 400 m parallel transect lines in each sub-plot. A total of 100 height measurements were taken from each sub-plot and the biomass (in kg/ha) was estimated using the following calibrated equation: $y = 0.004 + (0.5652*x)$, where y is the aboveground biomass (kg/ha) and x is the mean disc height (m). Basal cover was estimated using a 50 m tape measure as the basic sampling unit along the same transect lines. A total of eight sampling units were established per sub-plot and the distances along the tape measure intercepted by plants species were recorded; finally the distance covered by bare ground was calculated. In addition, sixteen quadrats of $0.5 \times 0.5\ m^2$ were established per transect line and the species within each quadrat were identified and quantified for computation of indices of species diversity: the Shannon-wiener index and Simpson index of diversity. Finally, canopy cover, botanical composition, and density of woody species were estimated using the point-centered quarter method (PCQ) (Cottam & Curtis 1956). Eight sampling points were established per transect line, making a total of sixteen sampling points per sub-plot. A cross was drawn in each sampling point and the four nearest trees, one from each quarter were measured. The distance of each tree from the marked center, the crown diameter, the height of tree (HT) and the height of the lowest browsable materials (LBM) were recorded.

Study II, was conducted in the Meatu district and assessed the effects of seasonal variation in quality and quantity of forage and the effects of exclosure management on the grazing behavior of cattle and goats. The study was 2 x 2 x 2 factorial design, with three independent variables each with two levels: season (rainy or dry), *ngitili* management (private or communal) and livestock species (cattle or goats). Two mixed herds of cattle and goats from two villagers of Buganza (48 cattle and 22 goats in private *ngitili*) and Mwambegwa (50 cattle and 25 goats in communal *ngitili*) were selected for observation. The two selected grazing exclosures (private vs. communal management), had comparable characteristics: both areas had a semi-arid climate and similar vegetation types namely wooded grassland dominated by acacia woody species. Prior to behavioral observations, the aboveground herbaceous biomass and bulk density were estimated through clipping, drying and weighing herbaceous vegetation as described by Abanda et al. (2011). Behavioral observations were made in two consecutive seasons: one rainy season (February-March 2012) and one dry season (July 2012).

The scan and focal observations followed Altmann (1974) and Sibbald et al. (2005). Four observers scanned the whole group of animals for 5 minutes at 5-minute intervals to estimate the percentage of animals grazing, browsing, walking, ruminating, and performing other activities. During focal observations, four observers were assigned to four animals (two cattle and two goats from each herd) to record the time animals spent on grazing, browsing, walking, ruminating, idling, and other activities. Each focal period lasted for 5 minutes with 5-minute intervals between each bout. The observers also recorded the number of patches visited and identified plant species eaten by their focal animals in every 5-minute observation bout. Finally, the five most abundant forage species were sampled and taken to the Sokoine University of Agriculture (SUA) for chemical analyses. Proximate analysis was used to determine dry matter (DM) content, crude protein (CP) and ash. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the method of Van Soest and Robertson (1991). Both *in vitro* dry matter digestibility (INVDMD) and *in vitro* organic matter digestibility (INVOMD) were determined by the two-stage techniques of Tilley and Terry (1963).

Study III, was carried out in a 111.6 acres reserved (deferred) pastureland at the Haydom Farm and Development Ltd. in Hanang district to evaluate the growth performance and behavior of Zebu cattle on natural pasture following concentrate supplementation. Vegetation composition and the physical characteristics and chemical composition of key forage species from the exclosure were determined prior to behavioral observation. Chemical composition of forage and concentrate samples were analyzed at the Department of Animal Science and Production (DASP), SUA, following AOAC (2002) procedures. NDF and ADF were analyzed by the method of Van Soest and Robertson (1991), while INVDMD and INVOMD were determined using the two-stage techniques of Tilley and Terry (1963). Behavioral observations were undertaken in two consecutive years: 2012 and 2013. In 2012, behavioral observations involved eight Zebu steers that were distributed into two dietary groups of four animals: the diet of one group was pasture + concentrate (PS) and the diet of other group was pasture alone (NP). In the following year, 2013, twelve steers were studied in the same dietary treatment groups but with shorter period of finishing. In 2012 the finishing period was 90 days, while in 2013 it was only 60 days. Animals in the PS group were given 4 kg DM concentrate (per animal) daily at 7.00 am (before being released to the pasture) and at 6.00 pm upon return from pasture. The concentrate mixture was formulated from maize bran (70 %), sunflower seed cake (27 %), mineral mix (2 %) and salt (1%). All animals were monitored throughout the course of their study period, with records taken of their body weight, estimated body condition scores, and their behavioral patterns observed on pasture using the focal observation method described by (Lehner 1996). Four experienced observers, each assigned to one focal animal per day, recorded the time that the animal spent feeding, walking, ruminating, idling, and doing other activities. The observers also recorded the number of patches visited by their focal animal, the number of bites taken and identified the plant species eaten in every five-minute bout. While a patch is defined as the spatial aggregation of bites over which the instantaneous bite rate remains relatively constant (Baumont et al. 2000), a bite is considered as the head movement associated with severance of a bunch of herbage gripped in the mouth (Avondo et al. 1995).

Study IV was also carried out at the Haydom Farm and Development Ltd, from November 2012 to February 2013, and evaluated the effects of two regimes (dry season natural pasture grazing alone compared with total confinement with free access to wheat straw and concentrate supplementation) on the carcass characteristics and meat quality of Tanzanian Zebu steers. The Zebu steers (n = 27), aged between three and four years, were distributed into the two dietary treatment groups: total stall feeding (SF, n = 16 animals) and natural pastures alone (NP, n = 11 animals). The SF animals were given wheat straw *ad libitum*, had free access to water and the group received 75 kg DM concentrate supplements daily (approximately 4.6 kg DM per animal). The live weights of animals were recorded at the start of the feeding trial and thereafter every two weeks until the end of experiment. Slaughtering and dressing were carried out at the Arusha abattoir following the standard procedure described by Bourguet et al. (2011). Temperature and pH of the left half of the carcasses were recorded at 45 minutes, 6, 12, and 24 hours postmortem. The chemical composition of *Longissimus dorsi* (LD) samples were determined at the DASP laboratory following AOAC (2002) procedures. Tenderness of LD samples was determined using the Warner-Bratzler Shear Force (WBSF) machine (Zwick/Roell Z2.5, Germany; installed in the

DASP laboratory, Figure 2) as described by Van Oeckel et al. (1999). The dressing percentage was expressed as proportion of hot carcass weight to slaughter weight, and cooking loss was determined by measuring the weight change of meat samples after cooking at 80°C in a water bath for 1 hr. Color and marbling scores were assessed at the rib eye by a panel of three experienced people using a color chart and marbling grading system as described by Mapiye et al. (2009).

4 MAIN RESULTS

The aboveground herbaceous biomass was significantly higher in old private *ngitili* than in continuously grazed land (Figure 1; Paper I). Higher vegetation cover was found in *ngitili* than in the continuously grazed lands (Figure 2; Paper I). However, herbaceous biomass production and vegetation cover did not vary significantly with duration of protection (old *ngitili* compared with young *ngitili*) ($P > 0.05$). Neither grazing system nor age of protection had a significant effect on species diversity as based on the Shannon-Wiener index and Simpson index of diversity ($P > 0.05$). Although absolute densities of woody species tended to be independent of *ngitili* management and age of protection, the mean HT was significantly higher in old communal *ngitili* than young communal *ngitili* (Figure 3a; Paper I). The mean height of LBM was also significantly higher in old communal *ngitili* than in young communal *ngitili* and continuously grazed lands (Figure 3b; Paper I).

The key browse species (*Acacia tortilis, and Acacia nilotica*) sampled from grazing exclosures were found to have significant higher CP content than grass species (*Bothriochloa insculpta, Cynodon nlemfuensis* and *Eragrostis tenuifolia*). Indeed, NDF and ADF content were relatively higher in most key grass species than browse species (Table 1; Paper II). Wheat straw and the key forage species sampled from natural pastures tended to have relatively low levels of CP, high NDF and ADF, and reduced digestibility (INVDMD & INVOMD) compared with the feed ingredients constituting concentrate mixture (Table 1; Paper IV). Variations in season and management of ngitili were found to have influence on the quality and quantity of the key forage species. The CP contents and INVDMD were relatively higher in the key grass species sampled during rainy season than those sampled in the dry season. Moreover, most species sampled from the communal *ngitili* tended to have relatively higher levels of NDF and ADF, but had relatively lower levels of INVDMD (Table 1; Paper II). The aboveground herbaceous biomass, bulk density and sward height were significantly higher in the rainy season than in the dry season, for both private and communal *ngitili* (Figure 1; Paper II).

The behavioral observations revealed that cattle and goats behaved differently from each other on pasture. Cattle spent considerable more time grazing on herbaceous species and goats spent more time browsing woody species (Figure 2; Paper II). Goats were observed to feed more on *A. tortilis*, while cattle showed greatest preference for *Urochloa mosambicensis*, *E. tenuifolia* and *B. insculpta* (Figure 4; Paper II). Seasonal variations in the quantity and quality of forage influenced the behavioral activities of cattle and goats on pasture, as both spent significantly more time walking, ruminating, and idling in the dry season than in the rainy season (Table 2; Paper II). Both cattle and goats foraged crop residues more frequently in the dry season than in the rainy season and also more frequently in communal *ngitili* than private *ngitili*. However, the management of *ngitili* had less effect on the foraging time of cattle than of goats. Goats tended to spend considerably more time browsing in the communal *ngitili* than in the private *ngitili*, and considerably more time grazing in the private *ngitili* than in the communal *ngitili* (Figure 2b; Paper II). Focal observations also revealed that animals in the PS group spent significantly less time feeding on natural pasture than those in the NP group (Table 2; Paper III). However, cattle in this group (PS) spent considerably more time walking in the early hours of the day (morning) and spent more time ruminating at the afternoon (Figure 3; Paper III). Moreover, significantly higher numbers of bites per minute were observed in the NP group than in the PS group (Figure 4b). However, the number of patches visited was found to be significantly higher for cattle in the PS group than in the NP group (Figure 4a; Paper III).

The average daily gain (ADG) was significantly higher in the supplemented group (PS) than in animals grazed on natural pasture (NP) alone (Figure 1; Paper III). The weight gain in the PS group increased progressively with time, and was highest in 2013 during the short finishing period (Figure 1 & 2; Paper III). Animals fed on wheat straw with concentrate supplementation also displayed significantly higher values for ADG than animals grazed on pasture alone (Figure 1a; Paper IV). Dressing percentage (Figure 1b; Paper IV) and marbling scores values (Table 2; Paper IV) were significantly higher for the stall-fed group of steers than pasture-grazed steers. The initial carcass temperature for steers in the NP group was higher than for those in the SF group, but declined rapidly at 6, 12, and 24 hrs (Figure 2a: Paper IV). Some carcass linear measurements, such as length of hind leg (HL) and hind leg circumference (Circ.) were significantly higher in steers in the SF group than in the NP group. However, postmortem carcass pH, meat tenderness, meat chemical composition (moisture contents, DM, ash, EE, and CP) and color were apparently not influenced by concentrate supplementation.

Figure 2: Measuring pH and tenderness of meat using a portable pH-meter and the Warner-Bratzler Shear Force (WBSF) machine respectively at DASP laboratory-SUA.

5 GENERAL DISCUSSION

5.1 Forage conservation for utilization in the dry season

Forage conservation practice in the form of *ngitili* (i.e. deferred feeds) has been used for many years as a coping strategy in response to acute shortage of forage in the dry season among the agro-pastoral communities of the north-western regions of Tanzania. The present study revealed that *ngitili* can play an important role in vegetation recovery and accumulation of aboveground herbaceous biomass for livestock feeding in the dry season. The relatively higher aboveground herbaceous biomass and vegetation cover observed in *ngitili* compared with continuously grazed land, indicates vegetation recovery following seasonal resting. However, the estimated aboveground herbaceous biomass from *ngitili* in the study areas was relatively lower than those recorded in other African semi-arid exclosures, such as those of Kenya (Verdoodt et al. 2009), Ethiopia (Yayneshet et al. 2009) and South Africa (Abanda et al. 2011). For example, the mean values for biomass recorded from both the private and communal *ngitili* ranged from 550 -760 kg/ha (Figure 1; Paper I) compared with 1000 -1500 kg/ha of biomass recorded from exclosures in the semi-arid Tigray region, northern Ethiopia (Yayneshet et al. 2009). The differences in aboveground herbaceous biomass accumulation across semi-arid regions could be due to variations in time grazing area is rested, grazing intensity before resting, and seasonality of plant defoliation. High grazing intensity in the study area due to the large livestock population (NBS 2012; Wiskerke et al. 2010) and the long dry season together with unpredictable rainfall, are the factors that most likely contributed to the reduced accumulation of biomass. Moreover, variations in vegetation types and species composition can also affect the plant's abilities to tolerate grazing pressure, a factor that subsequently determines biomass accumulation.

The lack of difference in aboveground herbaceous biomass recorded from communal *ngitili* and from continuously grazed lands might imply that the use of *ngitili* in communal rangeland is of limited effect with respect to vegetation productivity. These findings are in agreement with those of Briske et al. (2008), who concluded that the deferred grazing system is not superior to the continuous grazing system on semi-arid rangelands. Low vegetation regrowth in the communal areas might be associated with the high grazing pressure due the large livestock population and inadequate grazing management. The Shinyanga and Simiyu regions have the largest livestock populations in the country that depend on communal rangelands. Hickman et al. (2004) indicated that animal density is a key management variable that influences vegetation recovery and that its impact overrides the effects of grazing management. According to Noy-Meir (1993), plants are adapted to tolerate grazing pressure through compensatory growth to a certain degree of defoliation, but high grazing intensity reduces the potential for regrowth of photosynthetic leaves following defoliation. Application of the deferred grazing system during the period of minimum growth associated with environmental stress may have little impact on vegetation recovery (Heitschmidt et al. 2005). According to Snyman (2003), application of management practices, such as excluding animals from grazing areas in severely degraded rangelands could not have positive effect on vegetation recovery. The anticipated benefits of deferred grazing on communal rangelands in the study area had not been realized, possibly because of the interactive effects of high stocking rate and persistent drought. According to Heitschmidt et al. (2005), periodic grazing or deferment during drought has minimal impact on vegetation production.

The low values of the aboveground herbaceous biomass, bulk density, and sward height, and the relatively poor nutritive values of the forage species observed in the communal *ngitili* compared with those in the private ones (Paper I and Paper II) might be associated with a lack of community responsibility in the management of communal resources. Quinn et al. (2007) pointed out that management of common pool resources in Tanzania faces several challenges, including lack of community accountability in the monitoring of resources held in common, poorly defined boundaries, and unclear rights for the users of resources. In communal *ngitili* management, the rights of entry and use of common resources are unclear and the decision-making powers are vested in a few village leaders or institutions, such as churches, mosques, and NGOS (Kamwenda 2002), that are not necessarily representative of the community members. Degradation of the communal *ngitili* in the study area might be associated with the Hardin's theory of tragedy of the commons, which held that, "resources held in common are subject of massive degradation" (Hardin 1968). Despite the view that degradation of communal resources is inevitable (Feeny et al. 1990; Hardin 1968), if these resources were managed properly then they could be utilized sustainably (Kissling-Näf et al. 2002; Quinn et al. 2007). For sustainable management of the communal *ngitili*, the reorganization of the institutions that manage them is essential if they are to fulfil their potential, and such institutions should clearly define the rights of resource users, provide a mechanism for monitoring the resources, and the decision-making powers should be participatory.

An alternative explanation for the notable decrease in herbaceous vegetation cover and aboveground herbaceous biomass in communal *ngitili* could be due to the competitive effects of woody plants and herbaceous layer. Although the present study could not find significant difference in the absolute density of woody species between the private and communal *ngitili*, a body of literature indicates that communal rangelands in Shinyanga and Simiyu regions have been intensively rehabilitated with woody species (Barrow & Mlenge 2003; Barrow & Shah 2011; Pye-Smith 2010; Selemani et al. 2012; Shechambo 2008). The higher density of woody plants in these regions was mostly due to the influence of the HASHI intervention programme. According to Shechambo (2008), within the last three decades about 500,000 ha of communal woodland have been restored in these regions through the HASHI programme. Despite the view that woody encroachment is a natural phenomenon (Britz & Ward 2006; Wiegand et al. 2006), human intervention has largely contributed to the increase in woody plant species in these regions. A decrease in herbaceous production in relation to the encroachment of woody plant species could most likely be a result of severe competition for available water and nutrients in the soil. According to Skarpe (1990), heavy grazing causes severe competition between woody plants and the herbaceous layer due to intensive utilization of grasses. Despite the important role played by woody plant browse as a cheap source of protein for ruminant livestock, an increase in woody plant density beyond a critical limit normally results in a reduction in the grazing capacity (Abule et al. 2007).

Although *ngitili* have been revived and seasonally rested for more than three decades in the north-western regions of Tanzania, the age of *ngitili* was not found to influence vegetation recovery. The aboveground herbaceous biomass, vegetation cover, species composition, and density of woody species did not vary significantly between *ngitili* started more than ten years ago and those of ten years and below. This might be due to the fact that all *ngitili* are subjected to heavy grazing pressure every year, and the short deferred period may be insufficient for vegetation recovery. According to Vallentine (2001), severely grazed plants are less capable of rapid regrowth following defoliation. Generally, *ngitili* are seasonally rested from November to June and open up for grazing between July and October every year. Whether a well-planned rotational resting could offer sufficient time for vegetation recovery, further investigation is needed. However, extrapolating from the reported experiences from several studies in other countries, between four to eight years of total exclusion from grazing is necessary to allow vegetation recovery (Fernández-Lugo et al. 2009), sufficient accumulation of biomass (Yayneshet et al. 2009), and improved soil quality (Medina-Roldán et al. 2012).

5.2 Livestock feeding and foraging behavior

In Tanzania, livestock are predominantly managed under traditional production systems as mixed herds, mainly of cattle, goats, and sheep. These free-ranging animals on natural pasture are subjected to the large seasonal variations in forage quality and quantity. The present study revealed large variations in the foraging habits of cattle and goats, a behavioral adaptation that presumably enables them to survive together in diverse environments with large variations in the quality and quantity of forage species. Cattle frequently grazed on poor quality grasses and crop residues, while goats selected highly nutritive branches and pods of acacia trees (Paper II). This may be because cattle have a large gut capacity in relation to their metabolic requirements (Celaya et al. 2007; Rook et al. 2004), and thus are able to digest fibrous feeds efficiently , while small ruminants such as goats require more energy (Silanikove 2000) and are thus adapted to the more digestible browse species. Despite most browses being characterized by containing high levels of secondary chemical compounds, goats, like other browsers, are able to tolerate toxic compounds from browse species (Hofmann 1989; Hoven 2010; Landau et al. 2000). The resource partitioning between these animal species underlines that their different adaptive feeding strategies may play an important role in reducing interspecific competition in the semi-arid environments where forage resources are usually scarce. However, during acute shortages of forage resources in the dry season, dietary overlap between cattle and goats was evident. Both cattle and goats preferred browse species, such as *A. nilotica*, and both cattle and goats selected more crop residues in the dry season. Given the high abundance of woody browses and plentiful crop residues in the dry season, tree fodder supplements and improved crop residues could be useful to alleviate the shortage of forage.

Seasonal variations in the quality and quantity of forage are considered to be the most important constraints to livestock production in the tropics (Agza et al. 2013; Ngwa et al. 2000). In Tanzania, forages are characterized by seasonal variations in quality and availability (Mtengeti et al. 2008), which, in turn, affects the preferences of free-ranging animals. Livestock are frequently exposed to low quality forage from communal rangeland in the dry season (Kakengi et al. 2001). This study reveals that reduced aboveground herbaceous biomass, bulk density, and nutritive values of the forage species in the dry season influenced the foraging behavior of both cattle and goats. Cattle and goats were found to spend considerably more time walking in the dry season than in the rainy season, apparently searching for higher quality forage. The notable lower bite rates, greater numbers of patches visited, and the extended time spent walking by cattle and goats might be related to forage depletion in the dry season. Baumont et al. (2000) pointed out that depletion of forage in a patch motivates animals to move on to find other patches with higher quality forage species. However, animals may trade off quality for quantity (Van der Wal et al. 2000), and switch to less preferred plant species, in order to save the time and cost used in searching for high quality species (Distel et al. 1995). This has been confirmed in this work, where plant species with low CP levels and high NDF (such as *B. insculpta, E. tenuifolia and C. nlemfuesis)* were eaten in fairly large quantities, probably because they were highly abundant in the grazing plots.

In addition to the effects of season on the foraging behavior of cattle and goats, variations in the physical characteristics of the vegetation between the private and communal *ngitili* had a marked effect on the foraging behavior of goats. In the communal *ngitili*, where the aboveground biomass and bulk density of herbaceous vegetation were very low, goats selected more browse species than in the private *ngitili*. The slightly higher availability of woody species in the communal *ngitili*, coupled with both morphological and physiological adaptation of goats, probably enhances the preference for browse. However, most woody species in the communal *ngitili* were too high up to be readily accessed by goats (Paper I). This was also evident from bipedal feeding and social facilitation feeding of goats, where some goats within the groups were frequently noted to be pushing down the branches of trees, and by so doing enabled other goats to feed more easily. Herders were also familiar with the natural vegetation preferred by livestock and, in some cases, were noted pulling down branches of trees and lopping off some of branches to facilitate accessibility of the animals to browsable materials.

Strategic supplementation with high-energy concentrate appears to have positive environmental implications. Cattle that received supplementation with locally made concentrate mixture tended to exert less pressure on herbaceous vegetation than non-supplemented cattle (Paper III). A decreased feeding time, together with fewer bites per minutes, as observed in supplemented animals may be associated with metabolic control. These findings have been supported by Lindström and Redbo (2000), who reported that feeding duration and feed intake of cattle on natural pasture decreased in animals that were supplemented with high levels of concentrates. The decrease in feed intake may be because of high concentrations of the volatile fatty acid (VFA) in the rumen. Animals fed concentrates tended to have rapid fermentation, leading to an increase in osmotic pressure due to the concentration of VFA in the rumen (Baumont et al. 2000). Strategic supplementation with locally available and affordable concentrates may enhance livestock productivity and reduce degradation of rangeland vegetation.

5.3 Effect of concentrate on weight gain, carcass characteristics and meat quality

The significantly higher ADG of animals fed on wheat straw as basal diet and supplemented with high-energy concentrate compared with those grazing freely on natural pasture (Paper IV) is attributed to the improved utilization of poor quality wheat straw following supplementation. This argument is supported by Khandaker et al. (1998) who reported that supplementation of animals with concentrate improves voluntary intake and digestibility of wheat straw. Concentrate feeds supplies energy and nitrogen which are required by rumen microbes to facilitate digestion of roughage, and consequently increased voluntary intake (Rokomatu & Aregheore 2006). In Tanzania, wheat cereal is one of the crops that yields substantial quantities of residues (about 130,000 tonnes per year) that can be used to reduce the shortage of forages especially in the dry season (Viggo 2008). However, due to its slow rumen degradability, it is important to improve its utilization by offering it in combination with locally available and affordable concentrate mixture.

Weight gain has a considerable economic effect on ruminant livestock in Tanzania, because animals are bought and sold on the basis of their live body weights. Despite weight gain of supplemented animals being significantly higher and increasing progressively with time, their ADG remained below the expected range (Paper III and IV) for cattle on a finishing diet (Meissner et al. 1995). Such relatively low gains might be associated with the production system, because the finished animals had been raised on poor diet pasture. Indigenous cattle, such as Zebu cattle that are raised on natural pasture exhibit low weight gain compared with the stall-fed animals (Muchenje et al. 2009a). Moreover, weight gains for the supplemented group could not be considered to be economically viable when compared with the price of production unless agro-pastoralists use their own locally produced by-products from milling, such as maize brain and sunflower seed cakes after crop processing. Tanzania is a major producer of maize and sunflower crops (Birch-Thomsen et al. 2001) that could be used as potential sources of maize brain and sunflower seed cake.

The relatively higher values for dressing percentage observed in the feedlot animals compared with pasture-grazed animals are in accordance with the findings of Camfield et al. (1999) and Steen et al. (2003). These values may be associated with differences in their growth rates that resulted in greater fat deposition in the muscles of the concentrate-fed animals. Significantly more intra-muscular fat was noted in the concentrate-fed animals than pasture-grazed animals as reflected by the higher marbling score values. Cattle with higher fat deposition in the muscles usually produce higher dressing percentage (Van Koevering et al. 1995). However, the values for dressing percentages of supplemented Zebu steers were below the expected range value (50 %) for steers under finishing diet (Bowling et al. 1978; Bruns et al. 2004; Gomes et al. 2012; Keane et al. 2006; Montgomery et al. 2009). These differences may be due to variations in breed types and the husbandry systems. The steers finished under this feeding trial were from poor quality pastures.

Although, rapidly growing animals tend to have tender meat, due to an increase in protein turnover (French et al. 2001), there was no significant difference in meat tenderness between concentrate-fed animals and pasture-grazed animals. These findings are in agreement with those of Lowe et al. (2002) and Moloney et al. (2001) who reported a poor correlation between animal growth rate and meat tenderness. Both concentrate-fed animals and pasture-grazed animals produced meat that required higher force (above 50 N/cm^2) to shear through, which is an indication of tougher meat. The high shear force values could be explained by factors other than growth performance, that can also affect meat tenderness, such as phenotypic traits and pre-slaughtering handling stress. Gomes et al. (2012) found a positive correlation between meat tenderness of steers and their phenotypic traits. Indigenous breeds such as Zebu cattle are characterized by greater amount of *calpastatins* which inhibit the activity of *calpains* and hence result in slower degradation of muscle postmortem.

Thus these animals tended to have tougher meat than exotic breeds (Muchenje et al. 2009a). On the other hand, Devine et al. (2006) considered pre-slaughter stress, due to transportation and handling as the major factor affecting meat tenderness. The experimental animals in the present study might have been subjected to pre-slaughter stress due to the long distance covered during transportation from the Haydom farm to Arusha abattoir (about 280 km away). Stressed animals tend to release high amount of catecholamines (Muchenje et al. 2009b) that influences the depletion of glycogen and subsequently affects postmortem tenderization.

6 CONCLUSION AND RECOMMENDATIONS

The deferred grazing system in the north-western semi-arid regions of Tanzania was found to be an important coping strategy enabling the Sukuma agro-pastoralists to alleviate the shortage of forage in the dry season. The higher aboveground biomass and vegetation cover observed in *ngitili* than in the continuously grazed land was an indication of vegetation recovery following the deferment. However, application of *ngitili* appears to have a limited effect on restoration of severely degraded communal rangelands in terms of aboveground herbaceous biomass, vegetation cover, and species composition. This may be attributed to lack of community responsibility in the management of communal resources.

Stocking animals in mixed herds was found to be beneficial due to resource partitioning between cattle and goats that reduced interspecific competition and enabled them to survive together in the poor quality environment. Despite the physiological and morphological foraging adaptation of cattle and goats, dietary overlap was evident during the acute shortage of forage in the dry season. Depletion in the quality and quantity of forage in the dry season, forced animals to spend more time walking around searching for high quality feed. However, strategic supplementation of animals with high-energy concentrate in the dry season improved their productivity and altered their foraging behavior thereby reducing the grazing pressure on rangeland vegetation. Increases in ADG and improved carcass characteristics were attributed to improved utilization of poor quality wheat straw following concentrate supplementation.

In order to improve agro-pastoral livestock production in Tanzania, institutions managing communal rangelands should be reorganized. Both formal and informal rules and codes of conduct that regulate the rights of users of common pool resources should be clearly defined. The decision-making power should be participatory and benefits accrued from common resources should be shared equally. A well-planned rotational grazing system that could offer appropriate time for vegetation recovery should be investigated. Locally available and affordable concentrate supplementation is recommended to enhance ruminant livestock productivity and reduce the degradation of rangeland vegetation. Other feeding strategies, such as use of crop residues treated with urea and quicklime and supplementation with fodder tree leaves, are recommended to alleviate shortage of forage in the dry season.

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PAPER I

African Journal of Range & Forage Science
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tarf20

The effects of a deferred grazing system on rangeland vegetation in a north-western, semi-arid region of Tanzania

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Published online: 11 Oct 2013.

African Journal of Range & Forage Science 2013: 1–8
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This is the final version of the article that is
published ahead of the print and online issue

AFRICAN JOURNAL OF
RANGE & FORAGE SCIENCE
ISSN 1022-0119 EISSN 1727-9380
http://dx.doi.org/10.2989/10220119.2013.827739

The effects of a deferred grazing system on rangeland vegetation in a north-western, semi-arid region of Tanzania

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Received 30 April 2012, accepted 11 July 2013

The present study assessed the effects of deferred grazing management on rangeland condition using aboveground biomass, vegetation cover and species composition as indicators of range condition. The experiment was based on traditionally conserved exclosures (*ngitili*). Data were collected in Shinyanga rural and Meatu districts, Tanzania, from October to November 2011. Five grazing strategies were compared: old private *ngitili*, young private *ngitili*, old communal *ngitili*, young communal *ngitili* and continuously grazed land. Aboveground biomass was significantly higher in old private *ngitili* than continuously grazed land, but there was no significant difference in amount of biomass between communal *ngitili* and continuously grazed land. The mean percentage basal cover was significantly higher in *ngitili* than continuously grazed land. The duration of protection (old *ngitili* compared with young *ngitili*) was not found to have any significant influence on both aboveground herbaceous biomass production and basal cover. The Shannon–Wiener index and Simpson index of diversity revealed no significant differences in species diversity among the different strategies. Both the continuously grazed land and communal *ngitili* were generally in poor condition and a special rehabilitation programme for improvement of these fragile grazing lands should be investigated.

Keywords: biomass, grazing management, *ngitili*, species diversity, vegetation cover

Introduction

Grazing management may have a considerable influence on the productivity of rangelands, through differential use in time, space and intensity (Vermeire et al. 2008). Uncontrolled grazing has increased pressure on African rangelands and thus contributed to loss of vegetation cover and alteration of plant species composition (Retzer 2006). Degradation of these rangelands has caused negative impacts on pastoral ecosystems in terms of forage production (Kassahun et al. 2008). Increasing human population pressure and encroachment of rangelands by other land uses have been attributed to deterioration of these rangelands (Vetter 2005).

In Africa, more than 60% of the land surface is covered by arid or semi-arid rangelands (Homewood 2004), where most of the pastoralists and agropastoralists derive their income and sustenance from livestock grazing (Kassahun et al. 2008). These pastoralists have different strategies for coping with feed shortages, such as reserving standing hay, using multipurpose trees, purchasing feed, migrating and, as a last resort, reducing the number of their animals. Other strategies involve changing grazing management practices, through careful designing appropriate grazing routes that enable the utilisation of high-quality rangeland resources by avoiding unpalatable plant species and excessive trampling of vegetation (Allsopp et al. 2007, Samuels et al. 2007). Some pastoralist communities, such as the Himba in Namibia and the Borana in Ethiopia, have traditional coping strategies in which some of their grazing lands are temporally protected during the rainy season, so that they can be grazed during the dry season (Aerts et al. 2009). In semi-arid parts of north-western Tanzania, the Sukuma people have a similar tradition of conserving forage during the rainy season to use as deferred feed for the livestock during the dry season when feed is scarce. These reserved grazing lands are locally known as *ngitili*. *Ngitili* have been viewed as an important instrument for rangeland rehabilitation and alleviation of forage shortages among the Sukuma people (Kamwenda 2002). However, reserved grazing lands, if not managed carefully, may result in social conflicts and foster rangeland degradation rather than contributing to rehabilitation (Verdoodt et al. 2010). For example, poor allocation of pastures that may favour some groups (clans or tribes) over the others can create inequity and social tension among pastoralists (Beyene 2010).

Ngitili evolved in the 1980s (Barrow and Mlenge 2003) out of pastoralists' rehabilitation initiatives that were started in response to acute shortage of forage resulting from overgrazing related to increased human population pressure. Initially, the management of *ngitili* was under the collective responsibility of community members represented by village or other community groups. Two types of *ngitili* are used in the Shinyanga region of Tanzania: private and communal *ngitili*. According to Selemani et al. (2012), private *ngitili* are slightly smaller in size (1–400 ha) than communal *ngitili* (1–500 ha). Communal *ngitili* are demarcated with the mutual consent of community members. They are normally managed by the village administration and/or institutions such as schools, churches, mosques or community groups. Private *ngitili*, however, are cared for by individual pastoralists. Accessibility and ownership of private *ngitili* is entirely based on birth-rights or close family ties, whereas communal *ngitili* are mainly based on an acquisition of land by village or other institutions (churches, mosques, schools and community groups) from village government authorities. As *ngitili* are not fenced, village officials are mainly responsible for management of communal *ngitili*. Moreover, traditional Sukuma institutions play a significant role in managing both communal and private *ngitili* (Pye-Smith 2010). According to Kamwenda (2002), these institutions are based on traditional village guards (*sungusungu*) and community assemblies (*dagashida*).

Recently, there has been greater focus on changing the management of *ngitili* from communal to private ownership. However, poor understanding of this dynamic institutional arrangement limits the practical success of the traditional forage conservation. This study seeks to explore the extent to which these social dynamics influence traditional forage conservation. Despite the fact that *ngitili* have been practiced in the Shinyanga region for about three decades, there is paucity of information on their effectiveness in restoring vegetation and, particularly, no clear understanding of the influence of *ngitili* management and age of protection on vegetation attributes such as aboveground biomass, cover, density and botanical composition. It was hypothesised that *ngitili* initiated for more than one decade under private management could have better condition in terms of vegetation recovery. In particular, the aim of this study was to assess the effects of *ngitili* management and duration of protection on the quantity of aboveground biomass, basal cover and the botanical composition of the traditionally conserved fodder banks.

Materials and methods

Study area

This study was carried out in the Shinyanga region, Tanzania. The Shinyanga region is located at 2–3° S, 31–31.5° E and altitude 1 000–1 500 m above sea level (Rubanza et al. 2007). Ecologically, most of the Shinyanga districts (Shinyanga rural, Shinyanga urban, Meatu, Maswa, Kishapu and Bariadi districts) are semi-arid with annual rainfall of around 600 mm (Wiskerke 2008). However, the western part of Shinyanga (Bukombo and Kahama districts) has a subhumid climate with annual rainfall of 1 200 mm (Wiskerke 2008). The rainfall peak is unimodal, normally falling from November to April, but there is considerable variation in rainfall pattern. Dry-season precipitation, from May to November, is under 50 mm y^{-1} (Kamwenda 2002). The landscape is mostly flat with isolated stone hills. The dominant woody species of the study area are *Acacia* (*Senegalia* and *Vachellia*) spp., including *A. drepanolobium* (*V. drepanolobium*), *A. nilotica* (*V. nilotica*), *A. polyacantha* (*S. polyacantha*) and *A. tortilis* (*V. tortilis*), and *Dichrostachys cinerea* is also relatively common. Historically, the region was mostly covered with miombo (*Brachystegia* spp.) and acacia woodlands, before a massive clearance programme aimed at eradicating tsetse flies was instigated by the colonial authorities in the 1920s (Pye-Smith 2010). The clearance programme was environmentally catastrophic, as it predictably led to the loss of vegetation cover. In addition to the clearance programme, the region has by far the largest livestock population (about 334 livestock km^{-2}) in the country (URT 2012), resulting in severe vegetation depletion (Wiskerke et al. 2010). Currently, human population density in the Shinyanga region is about 79 individuals km^{-2} (URT 2013), of which over 80% own and manage their livestock on private or communal *ngitili* (Kamwenda 2002).

Sampling procedures

The rangeland vegetation survey was carried out in the Shinyanga rural and Meatu districts from October 2011 to November 2011. Five grazing strategies (old private *ngitili*, young private *ngitili*, old communal *ngitili*, young communal *ngitili* and continuously grazed land) were selected for comparison, based on the grazing management and age of reserved land. Old *ngitili* are those that have been seasonally rested for >10 years and young *ngitili* are those initiated ≤10 years ago. All selected areas had a similar grazing history, and were rested from the onset of the rainy season (November) and remained closed to livestock up to the peak of the dry season (July) every year. However, for the course of this study, all selected *ngitili* remained closed up to the end of data collection. Although there were large variations in stocking rates for different *ngitili* in the study areas, the selected study sites had similar stock densities (approximately 1 animal ha^{-1}). From each strategy, two subplots ranging from 50 to 100 ha were selected (except for continuously grazed lands, where four subplots were selected) for sampling of herbaceous and woody vegetation. Therefore, all five grazing strategies were investigated in 12 designed subplots (two of each for old private, young private, old communal and young communal *ngitili*, and four for continuously grazed lands). A reconnaissance survey was conducted one week before commencement of the study to identify *ngitili* with homogeneous vegetation structure, similar grazing history and to mark the sites using a GPS device.

Direct measurements are commonly performed through clipping, drying and weighing vegetation. However, this is a destructive method, as well as being time-consuming and costly (Whitbeck and Grace 2006). In the present study, a disc pasture meter, which is a non-destructive and rapid method (Bransby and Tainton 1977), was used for estimating and comparing the aboveground herbaceous biomass in five grazing strategies. This equipment relates the settling height of an aluminium disc to the standing crop of the herbaceous layer (Trollope and Potgieter 1986, Dörgeloh 2002). The disc pasture meter was calibrated by clipping and measuring the aboveground biomass under the disc meter in relation to the height of aluminium disc. Fifty samples were clipped and measured from five different experimental plots (10 samples per plot) and their weights in kilograms per hectare were plotted against recorded heights.

The linear equation obtained was: $y = 0.004 + (0.5652^*x)$, where y is aboveground biomass (in kg ha^{-1}), and x is the mean disc height in metres ($R^2 = 0.3329$). The equation was used to convert disc height to standing crop. After calibration, 50 disc pasture meter measurements were taken per transect line in two parallel transect lines, 100 m apart at each site. The transect line was 400 m long. The disc pasture meter was released at 8 m intervals along the transect line and the disc height recorded.

The botanical composition and basal cover of the herbaceous layer were estimated using the quadrat and line intercept methods developed by Canfield (1941) and tested by Cummings and Smith (2000). For basal cover, the line intercept method was used. A 50 m tape measure was used as a sampling unit and four sampling units were established per transect in two parallel transect lines 400 m long and 100 m apart. The distances along the tape measure that were intercepted by plant species were recorded, and from this data the distance covered by bare ground was calculated. For botanical composition, the quadrat method was used. Sixteen quadrats (0.5 m × 0.5 m) were established per transect line and the species within each quadrat were identified and the number of each individual species was recorded. Plant species that could not be identified on-site were collected and taken to the Sokoine University of Agriculture for identification. Two common indices of species diversity were computed: the Shannon–Wiener index (Spellerberg and Fedor 2003) and Simpson index of diversity (Nagendra 2002).

Canopy cover, botanical composition, density and woody plant structure were estimated using the point-centered quarter method, evaluated by Volpato et al. (2010). Eight sampling points were established along 400 m transect lines at 50 m intervals. A cross point was made in each sampling point from where the four nearest trees, one from each quarter, were selected. The distance of each tree from the centre, the crown diameter, the height of the tree (TH) and the height of the lowest browsable material (LBM) were measured and recorded.

Statistical analysis

Statistical analysis was carried out using the general linear model procedure of SAS (2004). One-way analyses of variance (ANOVA), including *post hoc* tests, were run to assess the effects of the five different grazing strategies on the aboveground herbaceous biomass, basal cover, absolute density and species diversity. The distribution of data for dependent variables were checked by the Anderson–Darling test using PROC in SAS (2004) and were normally distributed ($P > 0.05$). The means of the 12 subplots (two of each for private young, private old, communal young and communal old *ngitili*, and four for continuous grazed plots), calculated in MS Excel, were subjected to the following model: $y = (GM^*AG) +$ residual, where y is the dependent variable (aboveground herbaceous biomass, basal cover, absolute density, TH, height of the LBM and species diversity), and (GM*AG) is the five interaction effects of grazing management (GM) and age of *ngitili* (AG). Prior to the *post hoc* test, one-way ANOVA indicated some significant differences for the mean values of the five grazing strategies. The contrasts of the least square means (lsmeans) of the interactions were calculated and tested with the *F*-test.

Results

Aboveground herbaceous biomass

There was a significant difference in aboveground biomass between private *ngitili* and continuously grazed land (Figure 1). The lsmeans for aboveground biomass was significantly higher in old private *ngitili* than continuously grazed land ($P = 0.02$). However, *ngitili* under communal management did not differ significantly in aboveground biomass from either those managed privately or from continuously grazed land. Moreover, the duration of protection (old *ngitili* compared with young *ngitili*) was not found to have any significant influence on the quantity of aboveground herbaceous biomass ($P = 0.23$).

Herbaceous vegetation cover and composition

Management of *ngitili* was found to have a significant effect on herbaceous vegetation and bare ground cover (Figure 2). Higher vegetation cover was found in private *ngitili* than communal *ngitili* ($P = 0.02$) and continuously grazed land ($P = 0.0001$). As with aboveground biomass, the duration of protection (in terms of age within *ngitili* groups) had less significant effect on herbaceous cover. A significant difference was found only between old private *ngitili* and young communal *ngitili*; there was a significantly greater extent of bare soil in young communal *ngitili* than in old private *ngitili* ($P = 0.005$).

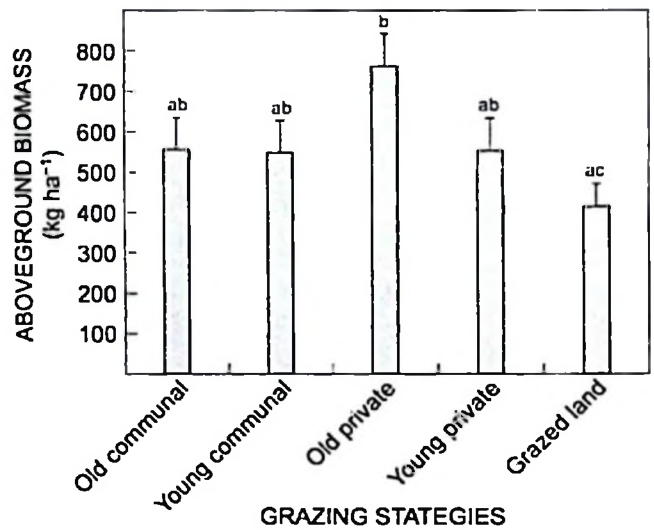

Figure 1: Aboveground biomass (kg ha^{-1}) measured in five different grazing strategies. Bars with the same letter are not statistically different ($p \leq 0.05$)

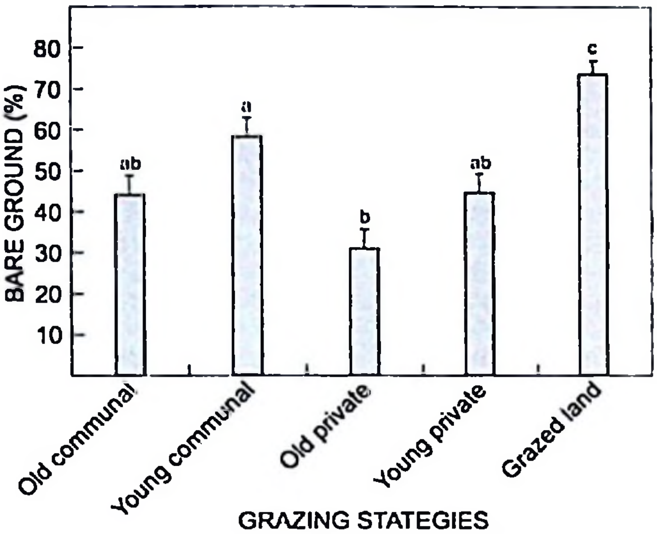

Figure 2: Means of bare soil (as a percentage) measured in five different grazing strategies. Bars with the same letter are not statistically different ($p \leq 0.05$)

A total of 16 herbaceous species were identified in the study area during the field survey (Table 1). In the private *ngitili* more than 10 species were recorded, dominated by *Urochloa mosambicensis* (sabi grass) and *Cynodon nlemfuensis* (stargrass). The communal *ngitili* were dominated by *U. mosambicensis* and *Heteropogon contortus* (black spear grass), whereas in continuously grazed land the dominant herbaceous plants were *U. mosambicensis* and *Tridax procumbens* (tridax daisy). However, grazing management of *ngitili* (private or communal) was found to have no significant impact on species diversity based on the Shannon–Wiener index ($P = 0.79$) and the Simpson index of diversity ($P = 0.64$).

Woody plant species structure

Twenty-nine woody species were identified in the study area (Table 1), with the dominant species being *Acacia drepanolobium*, *A. nilotica*, *A. tortilis*, *Anisotes dumosus*, *D. cinerea* and *Ormocapum trichocarpum*. Management and age of *ngitili* were found to have no significant impact on absolute density of trees per hectare in the study area ($P = 0.78$), but there were slightly higher mean densities in old *ngitili* with highest in old communal *ngitili*. The lsmeans ± SE for densities (trees ha^{-1}) in each treatment were as follows: old communal *ngitili* 587.39 ± 70.69, young communal *ngitili* 553.63 ± 303.08, old private *ngitili* 570.62 ± 327.39, young private *ngitili* 362.29 ± 60.42 and continuous grazed land 500.85 ± 148.31. Significant differences with respect to woody plant species structure were observed (Figures 3a and b). The mean height of trees in old communal *ngitili* was significantly higher than those in young communal *ngitili* ($P = 0.04$), whereas the old communal *ngitili* had a significantly higher mean height of LBM than young communal *ngitili* ($P = 0.02$) and continuously grazed land ($P = 0.02$).

Table 1: Common woody and herbaceous plant species identified in the study area

Species	Number of individuals counted per 800 m transect line		
	Private *ngitili*	Communal *ngitili*	Grazed land
Woody species			
Acacia drepanolobium	28	21	3
Acacia nilotica subsp. *nilotica*	66	44	20
Acacia nilotica subsp. *kraussiana*	0	1	0
Acacia polyacantha	0	7	1
Acacia senegal	0	0	5
Acacia tortilis	49	34	57
Albizia amara	5	3	2
Anisole dumosus	11	4	36
Cassia siamea	1	1	11
Combretum mossambicense	1	20	0
Combretum zeyheri	0	1	0
Commiphora africana	1	0	4
Dichrostachys cinerea	25	38	36
Diospyros fischeri	5	13	12
Euclea undulata	0	0	3
Euphorbia spp.	3	0	0
Flacourtia indica	1	0	0
Grewia bicolor	0	4	9
Grewia similis	0	0	1
Harrisonia abyssinica	0	0	2
Kigelia africana	0	1	0
Lannea humilis	0	1	3
Leucaena leucocephala	1	5	0
Maerua parvifolia	0	2	0
Markhamia obtusifolia	0	6	1
Opilia amentacea	0	0	3
Ormocapum trichocarpum	1	20	29
Sterculia quinqueloba	0	2	0
Vitex doniana	0	0	1
Total	198	228	239
Herbaceous species			
Allium crispum (wild onion)	3	1	4
Aristida species	5	7	1
Bothriochloa pertusa	4	0	0
Cassia rostiata	11	10	7
Cenchrus ciliaris	0	1	0
Commelina benghalensis	0	1	8
Cynodon nlemfuensis	58	3	1
Cyperus rotundus	2	5	0
Digitaria eriantha	13	0	0
Heteropogon contortus	41	84	36
Hyparrhenia rufa	11	4	2
Indigofera indica	11	47	26
Sida glomerata	3	1	6
Stylosanthes scabra	4	30	19
Tridax procumbens	32	51	55
Urochloa mosambicensis	68	110	98
Total	266	355	263

Discussion

It is useful to have an estimate of the aboveground herbaceous biomass in rangeland management as it provides a figure on which to base an estimation of stocking rates. The aboveground herbaceous biomass recorded in this study from the north-western semi-arid

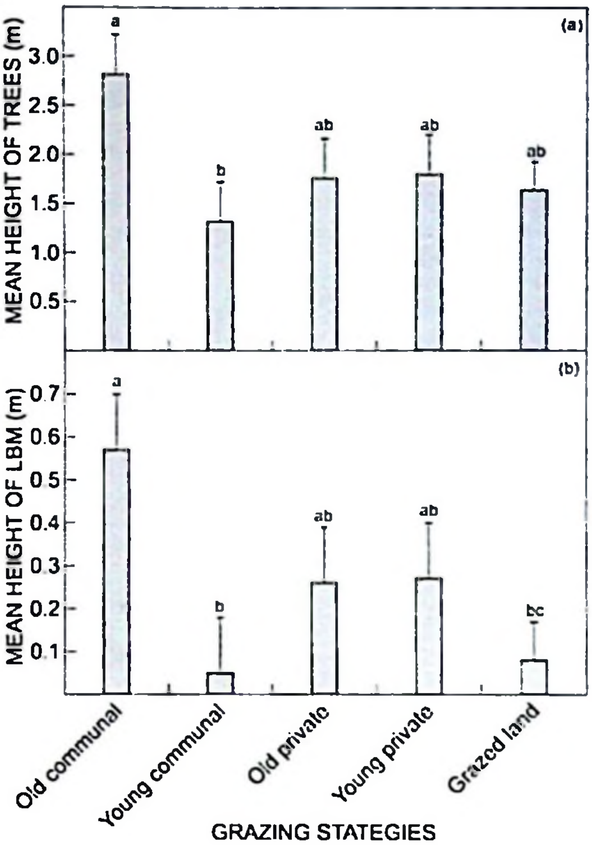

Figure 3: Combined effects of age of *ngitili* and their management on woody vegetation structure. (a) Mean height of trees (m) and (b) height of the lowest browsable material (m) measured from ground level. Bars with the same letter are not statistically different ($p \leq 0.05$)

region of Tanzania was lower than those recorded elsewhere in semi-arid African rangelands, such as Ethiopia (Yayneshet et al. 2009), Kenya (Verdoodt et al. 2009) and South Africa (Abanda et al. 2011). Livestock production in this region is limited by low aboveground biomass (Rubanza et al. 2007). The heavy grazing pressure in Shinyanga region (Wiskerke 2008), together with poor soil structure and very low natural soil fertility (Meertens et al. 1996), may be associated with the low biomass yield recorded in the study area. The difference in the aboveground herbaceous biomass in old *ngitili* and continuously grazed land implies that this traditional conservation of grazing areas has had the desired effect on vegetation recovery. However, the lack of difference in aboveground herbaceous biomass productivity between young *ngitili* and continuously grazed land suggests that the vegetation recovery process is very slow. Therefore, the use of *ngitili* may not help in the quick recovery of degraded rangelands and different strategies to ensure sustainable rangeland production, such as mechanical restoration techniques and oversowing with forage species, should be investigated.

Selection of species for oversowing should emphasise the need for drought-tolerant species, high dry matter yield, tolerance of low fertility soils and ease of propagation. Legumes species such as *Stylosanthes* spp. (*S. capitata*, *S. fruticosa*, *S. guianensis*, *S. hamata*, *S. humilis* and *S. scabra*) have been tested and have shown successful adaptation in semi-arid regions of Kenya and Tanzania (Thomas and Sumberg 1995). According to Dzowela (1990), improved strains of *Chloris gayana*, *Leucaena leucocephala*, *Panicum* spp. and *Pennisetum* spp. have also been planted and performed well in Kenya, Tanzania, Uganda and Zimbabwe. Nevertheless, few of these advances in agronomy have been passed on to traditional pastoralists in the Shinyanga Region, partly because of lack of motivation, competition between food and feed crops for land, unavailability and lack of inputs (seeds and fertilisers), and low market return (Owen et al. 2012).

The lack of difference in aboveground herbaceous biomass implies that the application of ngitili have no obvious benefits over continuous grazing in communal rangelands. These findings are supported by Briske et al. (2008), who report that, over the past 60 years, the anticipated benefits of a deferred system over continuous grazing have not been realised. Low yields in communal *ngitili* may be due to overutilisation of forage by different livestock herds as a result of poor grazing management. Despite the presence of customary institutions (*sungusungu* and *dagashida*), total exclusion of grazing in communal *ngitili* and control of stock number within ecologically sustainable carrying capacity is hardly possible. Lack of community responsibilities in the management of communal *ngitili* may be associated with low economic return. The resources and benefits accrued from communal *ngitili* are not shared equally, because the management system overlooks the overlapping rights of different users. In the management of communal *ngitili*, decision-making powers are vested in the village leaders or institutions (e.g. churches, mosques and NGOs), and these are not necessarily representative of the other community members (Kamwenda 2002). This is because the rational behaviour at the individual level is normally one of self interest and consequently affects the whole community (Bajema 1991). Generally, management of communal semi-arid rangelands in Tanzania is constrained by several challenges including poor monitoring (Quinn et al. 2007). Increased crop production in Sukumaland (Meertens et al. 1999) and an absence of clear boundaries in communal rangelands (Quinn et al. 2007) have also resulted in shrinkage and overexploitation of communal *ngitili*.

It has been widely believed that degradation of communal resources is inevitable (Feeny et al. 1990), unless the resource is converted to private or public property where the rights to entry and use of the resources can be restricted (Hardin 1968). However, recent studies have shown that communal resources, if managed properly, can be utilised sustainably (Kissling-Näf et al. 2002, Quinn et al. 2007). For sustainable utilisation of communal *ngitili*, rearrangement of institutions managing them is essential. This should involve an instigation of a well-coordinated mechanism that clearly defines the rights of users and means of regulations governing the use of *ngitili*. Institutions should include both formal (by-laws) and informal (codes of conduct and modes of behaviour) rules that will regulate rights to access, use, control and monitoring of communal *ngitili* (Quinn et al. 2007).

The lack of difference in aboveground herbaceous biomass production in relation to the duration of *ngitili* conservation may be associated with the partial withdrawal of grazing animals from *ngitili*. Most of the *ngitili* in the study area are protected during the rainy season (November to June) and grazed during the peak of the dry season (July to October) when feed is scarce. This short period of protection may not offer sufficient time for vegetation recovery, and long-term grazing exclusion may be required to see an improvement in biomass production. A well-planned rotation of resting may be of benefit in this region by enabling regeneration of plant species and thus increasing the amount of aboveground biomass. Borrowing experience from semi-arid exclosures in Ethiopia, an appropriate resting time that allows vegetation recovery and adequate accumulation of aboveground herbaceous biomass is between five to eight years of total exclusion from grazing (Yayneshet et al. 2009). Fernândez-Lugo et al. (2009) noted vegetation changes after four years of grazing exclusion, whereas Medina-Roldan et al. (2012) observed improved chemical soil composition after seven years of grazing exclusion. However, Muller et al. (2007) cautioned that 'there is no universally applicable grazing rotation system', and specific rangeland conditions must be taken into consideration. Furthermore, Hai et al. (2007) noted that other factors affect the recovery rates of vegetation, such as plant species' structure and function, physical soil structure, chemical soil properties and climate.

Reduction in total herbaceous vegetation cover and species composition in most African semi-arid rangelands is associated with heavy grazing (Hein 2006, Kassahun et al. 2008). The notable decrease in total vegetation cover in continuously grazed lands in the study area was therefore probably because of heavy grazing pressure. The significant difference in mean percentage basal cover between protected and non-protected areas is indicative of high livestock grazing pressure in the continuously grazed lands of this trial, resulting in a negative effect on herbaceous vegetation production. According to Snyman (2005), severe grazing may reduce both canopy and basal cover of rangelands. The consequences of such a reduction in vegetation cover can be linked with poor yields in aboveground herbaceous biomass in this region (Rubanza et al. 2007). As semi-arid areas are highly sensitive to grazing pressure, such changes may lead to the deterioration of rangeland and a reduction in grazing capacity.

Increases in woody species, accompanied by a decrease in herbaceous production and changes in species composition, are characteristic of poor rangeland management (Tefera et al. 2007). The slightly higher density of woody plant species in old communal *ngitili* in the study area can be linked with an observed reduction in total herbaceous vegetation cover and aboveground biomass production. The generally high density of woody plants may be due to community initiatives and an intervention programme aimed at restoring degraded rangelands in this region. According to Barrow and Mlenge (2003), communal *ngitili* in this region have recently been extensively forested in response to pastoralists' and agropastoralists' enthusiasm and the help of the Environmental and Soil Restoration Programme widely known in Swahili as '*Hifadh Ardhi Shinyanga*' (HASHI). According to Shechambo (2008), in 2008 an estimated 500 000 ha of woodland have been restored, a substantial increase from 600 ha in 1986. In addition to that, heavy grazing pressure in these areas appears to be directly proportional to encroachment of woody plant species (Wiskerke et al. 2010), and inversely proportional to aboveground herbaceous biomass production and vegetation cover (Rubanza et al. 2007). Tefera et al. (2007) supported the notion that an increase in woody vegetation has often been associated with heavy grazing. Furthermore, Abule et al. (2007) suggested that a decrease in herbaceous production because of woody encroachment results directly from severe competition for available soil, water and nutrients.

The predominant woody plants in the study areas are *Acacia* species that may reflect an overgrazed land. Acacia trees have the ability to tolerate heavy grazing pressure and thrive well in degraded rangelands. According to Tefera et al. (2007), a high density of *Acacia* species indicates that a rangeland has been overutilised over a long period. However, the leaves and pods of *Acacia* species have high nutritional value and are therefore useful, especially for feeding goats. Rubanza et al. (2007) found that dietary supplementation of ruminants on low quality basal roughages with the leaves and pods of *Acacia* trees provided a cheap and affordable crude protein supplement and resulted in improved weight gain of animals in the study area. However, most of these *Acacia* species contain substantial amounts of phenolic compounds (Salem et al. 2006), which can reduce their nutritional value. Moreover, seeds of *Acacia* trees are easily propagated by browsers, thus resulting in an increase in the absolute density of trees, further contributing to the competition with herbaceous vegetation.

Estimation of the height of LBM is crucial in semi-arid regions, as it allows an appraisal of the browsing capacity of the area. The significant differences in the mean heights of LBM of woody plant species under the different grazing strategies are most likely the result of different levels of browsing pressure. Despite the higher density of woody plants in old communal *ngitili*, they were rarely accessed by browsers because the height of LBM was significantly higher. Skarpe et al. (2007) suggested the browse biomass preferred by goats is made up by those plants which are at a level that is accessible to the animal (lower than 1.2 m). In continuously grazed land and young communal *ngitili*, most woody plant species were heavily browsed and were severely damaged, to the extent that new shoots from these plants sprouted very close to ground level (0–0.2 m high). However, newly sprouting tree shoots are of poor nutritional quality compared with large trees (Nordengren et al. 2003), because of the greater amounts of defensive chemicals in juvenile trees (Hattas et al. 2011). Therefore, availability of browse materials within the browse zone does not necessarily determine the forage available for browsing animals.

The lack of variation in species diversity between *ngitili* and the continuous grazed land was not anticipated. Decline in species diversity in several exclosures has been reported (McNaughton 1983), and in most cases this has been attributed to an increase in the species dominance following grazing exclusion (Belsky 1992, Milchunas et al. 1988). As most of the *ngitili* are grazed every year, grazing intensity possibly did not favour the increase in the dominant species that would narrow down species diversity. Bestelmeyer et al. (2003) outline several other factors that can determine species diversity, such as variation in physical and historical factors (soil, fire and other disturbances). As all the areas included in this study had approximately homogeneous physical structures and similar grazing histories, species diversity should perhaps not be expected to demonstrate much variation.

Conclusion

This study found that the *ngitili* deferred grazing system had little effect on rangeland vegetation, in terms of aboveground biomass production, herbaceous vegetation cover and the structure of woody plant species. Total reduction in aboveground herbaceous biomass and herbaceous vegetation coverage in communal *ngitili* and continuously grazed lands may be attributed to heavy grazing pressure. A lack of difference in aboveground biomass and mean basal vegetation cover between communal *ngitili* and continuously grazed lands may be associated with poor institutional management of common resources. The results of this study indicate that for sustainable utilisation of these vital rangeland resources, reorganisation of management is essential. Institutions should instigate both formal and informal rules, codes of conduct, and modes of behaviour that regulate obligations and rights of resource users. Moreover, a special rehabilitation programme, including interventions such as mechanical restoration techniques and oversowing of forage species, should be investigated for severely degraded *ngitili*. As partial withdrawal of grazing animals in communal *ngitili* failed to rehabilitate severely degraded rangeland in the study area, a well-planned rotational system is recommended, with longer-term grazing exclusion to allow for vegetation recovery.

Acknowledgements — The authors would like to thank the Natural Resources and Agro-forestry Centre (NAFRAC) and Tanzania Traditional Energy Development and Environmental Organization (TaTEDO) in Shinyanga for providing transport, support and research assistants during data collection. We also thank staff members of the Department of Animal Science and Production at Sokoine University of Agriculture for their help in identifying some of the plant species. The fieldwork was financially supported by the Department of Animal and Aquaculture Science (IHA) at the Norwegian University of Life Science (UMB) in Norway.

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PAPER 2

Livestock Science 157 (2013) 173–183

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci

Variation in quantity and quality of native forages and grazing behavior of cattle and goats in Tanzania

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ARTICLE INFO

Article history:
Received 26 January 2013
Received in revised form
31 July 2013
Accepted 2 August 2013

Keywords:
Season
Ngitili management
Forage
Grazing
Behavior

ABSTRACT

The study was conducted to assess the effects of seasonal variation in the quality and quantity of pasture and management of livestock exclosures (*ngitili*) on the grazing behavior of cattle and goats. The study was 2 × 2 × 2 factorial design with three independent variables: season (Dry or Rainy), *ngitili* management (Private or Communal) and animal species (Cattle or Goats). Focal and scan observation methods were used to record different behavioral activities. Vegetation attributes from the study areas were measured in two consecutive seasons. Most key forage species had significant higher crude protein (CP) content and *in vitro* organic matter digestibility (INVOMD) in rainy than in dry season ($P < 0.05$), but Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) did not vary significantly with season ($P > 0.05$). ADF and NDF were significantly higher in species from communal *ngitili* than those from private *ngitili* ($P < 0.05$). Above-ground herbaceous biomass and bulk density (BD) were significantly higher in the rainy season and in the private *ngitili* than in the dry season and in the communal *ngitili* respectively. Cattle and goats spent considerably more time grazing and browsing respectively in the rainy season than in the dry season ($P < 0.05$). Cattle foraging activities did not vary significantly ($P > 0.05$) with *ngitili* management, but goats found to spend considerably more time browsing in the communal *ngitili* and more time grazing in the private *ngitili* ($P < 0.05$). Despite the merits of stocking cattle and goats together in the heterogeneous pasture, seasonal variation in forage resources requires investigation of other strategies such as use of multipurpose trees and treatment of crop residues to improve livestock production.

1. Introduction

Ruminant production in Tanzania depends mainly on communal semi-arid rangelands (Rubanza et al., 2003). More than 70% of the ruminant livestock population of Tanzania kept in north-western and central parts of the country: Shinyanga, Simiyu, and Mwanza Manyara (Mwilawa et al., 2008; URT, 2006). In particular, the Shinyanga and Simuyu regions have the largest livestock population in the country with a total of 3.6 million cattle, 1.9 million goats and 0.7 million sheep (URT, 2012). According to Rubanza et al. (2007) these regions are characterized by scarcity of feed, especially during the dry season. Despite the scarcity of forage, the livestock production in these regions has sustained the livelihoods of pastoralists and agropastoralists for decades. Livestock owners in these areas have different coping strategies, including traditional conservation of forage to supplement livestock during acute shortage of feeds, and

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http://dx.doi.org/10.1016/j.livsci.2013.08.002

seasonal mobility in search of forage and water. However, climate variability (Rowhani et al., 2011), along with an increase in human (Meertens et al., 1999) and livestock (Wiskerke et al., 2010) populations in these regions, have increased pressure on grazing lands, and therefore traditional grazing practices need to be modified accordingly.

Grazing management can significantly affect the quality and quantity of pasture and subsequently grazing behavior of free ranging livestock (Cozzi and Gottardo, 2005). In the study area, the most common tradition grazing management is deferred grazing system, in which a piece of land is reserved during rainy season to be used in dry season when feed is scarce. These traditional exclosures are known as *ngitili* and two types are common in the study area: private and communal *ngitili*. Managements of these two exclosures vary in the extent that can contribute to variation in the quality and quantity of available forage resources. While private *ngitili* are managed by individual pastoralists, communal *ngitili* are managed under collective responsibilities of community members. The communal *ngitili* in the Shinyanga and Simiyu regions have been reported to be in poor conditions compared to private *ngitili* (Selemani et al., 2012). Generally, over-exploitation of communal rangelands resources in Tanzania has been associated with lack of community responsibilities and absence of clear boundaries (Quinn et al., 2007).

Seasonal variations in the quality and quantity of forages are considered to be among the most important constraints to livestock production (Ngwa et al., 2000). Despite the clear evidence that physical structure and chemical composition of forages vary greatly from season to season (Bennett et al., 2007; Kennedy et al., 2007; Safari et al., 2011; Yayneshet et al., 2009) yet, the interaction effects of seasonal variation and *ngitili* management on animal behavior have not been explored in the study area. This study investigated how seasonal fluctuation, in terms of physical and chemical composition of forages and *ngitili* management affect the behavioral activities of mixed herds of cattle and goats grazing on native pasture. Knowledge on this interaction can be harnessed for improving the management of grazing animals. In particular, this knowledge could be used to optimize forage allocation to different grazing ruminants and enable herders to identify vegetation attributes on which to base the rangeland restoration practices.

2. Material and methods

2.1. Study area

The study was conducted in northwestern Tanzania, Simiyu region, formerly part of Shinyanga region. This new region was administratively established in March 2012 and forms part of the Sukumaland. Simiyu region encompasses five districts: Meatu, Maswa, Bariadi, Busenga, and Itilima, and the present study was carried out in Meatu district. The region is characterized by semi-arid climate (Dercon, 1998). The rainfall in this area is bimodal with mean annual rainfall ranging from 600 to 800 mm (Rubanza et al., 2005). Data from the Tanzania Meteorological Station (TMS) indicated that the mean ambient temperature in the study area during the period of behavioral observation ranged from 18.3 °C (minimum) to 29.8 °C (maximum) for both seasons. The landscape is mostly flat and largely covered with wooded grassland (Wiskerke, 2008). The dominant woody species in the study area were *Acacia tortilis* (umbrella thorn acacia),, *Acacia nilotica* (scented-pod acacia), *Dichrostachys cinerea* (sickle bush) and *Anisotes dumosus* while herbaceous cover was dominated by *Bothriochloa insculpta* (sweet pitted grass), *Urochloa mosambicensis* (sabi grass), *Cynodon nlemfuensis* (Africa star grass) and *Eragrostis tenuifolia* (elastic grass).

2.2. Sampling procedures

2.2.1. Study design and exclosures description

The present study was 2 × 2 × 2 factorial design with three independent variables, each with two levels: Season (dry or rainy), *Ngitili* management (private or communal) and Animal species (cattle or goats). Two mixed herds of cattle and goats belonging to two villagers of Mwambegwa and Buganza villages of Meatu district were selected for observation. The herds from Buganza and Mwambegwa were stocked under private *ngitili* and communal *ngitili* respectively. Herds selection was based on requirements for the proposed grazing management regime that one herd should be stocked under private *ngitili* and another under communal *ngitili*. Selected grazing sites were familiar to the study animals. The livestock owners were fully involved in the study, especially during pilot phases, in which observers were able to familiarize themselves with the study animals and the grazing areas. The pilot phases were done 1 week prior to the observation phases for each season.

The two exclosures used in this study differed in terms of ownership and grazing management. However, they had similar ecological and climatic characteristics. Both areas have semi-arid climate with similar vegetation type. The common vegetation types were Acacia open woodland. The herbaceous vegetation covers in both *ngitili* were dominated by *B. insculpta*, *U. mosambicensis*, *C. nlemfuensis* and *E. tenuifolia*. A previous work (Selemani et al., in press) indicated that the two exclosures did not vary significantly in terms of herbaceous vegetation composition and density of woody species. The distance between the two studied *ngitili* was approximately 20 km. These areas were inhabited by Sukuma agro-pastoralists practicing typical subsistence mixed crop-livestock farming. Cattle and goats were the common livestock species and the dominant crops were maize (*Zea mays*), sorghum (*Sorghum bicolor*) and Rice (*Oryza glabaerreima*). The two selected exclosures were close to villagers' farms and therefore in dry season livestock had free access to crop residues after farmers harvesting their crops.

The communal *ngitili* was demarcated with mutual consent of community members and was managed by Mwambegwa village government. It was initiated since 1980s and has been seasonally rested for more than 30 years. The size of this exclosure was approximately 80 ha. This *ngitili* was used as income generating assert for the village government and was seasonally hired to pastoralists for livestock grazing especially in dry season when forage is scarce. During the time of data collection, it was engaged by one village member with herd size of 75 animals: 50 cattle and 25 goats. On the other hand, the private *ngitili* was owned by one agro-pastoralist from Buganza village with herd size of 70 animals: 48 cattle and 22 goats. The size of private *ngitili* was 66 ha and its management was entirely based on family responsibilities.

2.2.2. Behavior study

Observations were made during the course of two consecutive seasons: one rainy season (February–March, 2012) and one dry season (July, 2012). The scan and focal observation approaches described by Altmann (1974) and Sibbald et al. (2005) were used in this study. For scan observation technique, four trained observers used to scan the whole group of animals in 5 min with interval of 5 min and estimated percentage of animals grazing, browsing, walking, ruminating, idling and/or performing other activities. Each observer made a total of 14 observation bouts per day. The scores from each individual observer were taken as repeated measurements.

For focal observation technique, four animals (two cattle and two goats) from each herd were selected for observation. None of the selected animals were lactating or pregnant or had any known physiological problem. All the study animals were labeled with identification numbers (ID) to simplify data recording. Four observers were used, with each observer assigned to one focal animal to record the time that animal spent for grazing, browsing, walking, idling, ruminating and other activities. For the course of this study, observers considered animal to be idling if standing/or lying alone with no sign of rumination (regurgitation and jaws' movement). The category of other activities were including rubbing against trees, fighting, playing, drinking, defecating, urinating and agonistic behavior. Stopwatches were used to record time periods per activity during data collection. In order to avoid bias due to systematic errors, observers were switched from one focal animal to another every day. Observation was done in periods of 5 min bout with 5-min intervals between each bout. Observation was conducted in two sessions every day: 2 h in the morning (from 9:00 AM to 11:00 AM) and 2 h in the evening (from 3:00 PM to 5:00 PM) for a period of 8 days in each season. Similar to scan observation, each observer made a total of 14 observations bouts per day.

The observers also recorded the number of patches visited and identified plant species eaten by their focal animal in each 5-min bout. For the purposes of this study, a patch is defined as a spatial aggregation of bites over which instantaneous intake rates remain constant (Baumont et al., 2000). A focal animal was considered to be in one patch for as long as it remained stationary before moving to the next area. The individual plant species were recorded as zero or one count in each observation bout (zero means that plant was not eaten in that particular bout and one means the plant was eaten) per focal animal. The sum of counts for each individual plant species (recorded from 1 to 14 observation bouts) per day were taken as eating scores of that particular plant species by focal animal per day.

2.2.3. Herbaceous vegetation sampling and measurement

Prior to behavioral observation, the above-ground biomass and bulk density (BD) were estimated in the study area. Two parallel transect lines, 250 m long and 100 m apart, were established in each *ngitili*. Along the transect lines, a square quadrat (0.25 m × 0.25 m) was dropped at intervals of 10 m. The swards' height (SH) was measured within the quadrat and all vegetations within the quadrat were clipped and weighed. Samples were dried at 105 °C and the weights of dry matter (DM) and BD were calculated. BD was estimated as weight of DM in kg/volume of sward (sward volume calculated by multiplying the area of quadrant and sward height).

2.2.4. Chemical analysis

From each *ngitili* samples of forages that were abundant were collected for chemical analysis. Five forage samples were taken to the laboratory of the Department of Animal Science and Production, at Sokoine University of Agriculture (SUA). Proximate analysis procedures were used to determine the chemical composition of forages; DM, crude protein (CP) and ash. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the method of Van Soest and Robertson (1991), while *in vitro* dry matter digestibility (INVDMD) and organic matter digestibility (INVOMD) were determined by the method of Tilley and Terry (1963). Total ash was determined by ignition of feed samples at 550 °C for 3 h until all carbon had been removed. CP was calculated from nitrogen contents of feed determined by the Kjeldahl technique.

2.2.5. Statistical analysis

The General Linear Model (proc GLM) of SAS (2002) was used to analyze the results of chemical composition, *in vitro* digestibility and physical characteristics of feed samples. The model used was: y (% of DM, CP, ash, NDF, ADF, INVDMD, IVOMD & BD (kg m^{-3}), SH (m) biomass (kg ha^{-1}))=Season (dry and rainy)+*ngitili* management (communal and private)+forage species+forage species × season+forage species × *ngitili* management+residual. Least square means' (lsmeans) differences were tested by *t*-test.

For behavioral activities, proc mixed model of SAS (2002) was employed to analyze the fixed main effects (season, *ngitili* management and animal species) and interaction effects (Animal species*Season+Animal species*Ngitili* management) on foraging activities. The model used for focal observation was: y (time in minutes taken for grazing, browsing, ruminating, walking, idling and others)=Season+*Ngitili* management+Animal species+Animal species*Season+Animal species**Ngitili* management +Time of day (AM or PM) +Days (8 days in each season)+Observers (4 persons in each herd)+Residual. Observers, days and Residual were treated as random effects in this model. For scan observation, Animal species and its interactions were excluded in the above model, whereas interaction between Season and *Ngitili* management was included. The lsmeans differences were tested with t-tests.

Eating scores of forage species that were recorded at least once per day in every focal animal were subjected to the proc mixed model of SAS (2002). The original scores did not confirm to the normality and hence a natural log transformation was applied to stabilize the scores to conform to the linear model above. To overcome the effects of zero scores during log transformation, a 0.5 factor was added to the scores; log (scores+0.5) as described by Cox (1970). However, the statistical-test results for log transformed scores were similar to untransformed scores. The main effects of season, *ngitili* management and animal species for both log transformed scores and untransformed scores were not significant and excluded from the model. For presentation of results the estimated lsmeans for untransformed scores were presented. The model used was y (eating scores)= forage species+forage species season × animal species+forage species × *ngitili* management × animal species+residual. Residual was treated as random effects. Observers and days were removed from the model because their variance components could not be found (they come out as zero or very close to zero) when treated as random effects. The model effects were tested with *F*-tests.

3. Results

3.1. Chemical composition and in vitro digestibility of key forage species

Chemical composition and *in vitro* digestibility of five key forage species are presented in Table 1. Browse species, *A. tortilis* and *A. nilotica*, were found to have significantly higher levels of CP than grasses species; *B. insculpta*, *C. nlemfuensis* and *E. tenuifolia* in both seasons ($P<0.05$). However, NDF was significantly higher in grasses than browse species ($P<0.05$). Season was found to affect CP, INVDMD and INVOMD. Four key forage species out of five displayed significant higher CP ($P<0.05$), and three out of that had significant higher INVDMD and INVOMD ($P<0.05$) in rainy season than dry season. Three key forages species out of five were found to have significant higher NDF and ADF in communal *ngitili* than in private *ngitili* ($P<0.05$). Moreover, significantly lower levels of INVDMD and INVOMD were found in species sampled from communal *ngitili* than those from private ones ($P<0.05$).

3.2. Vegetation physical attributes in the study area

The combined effects of seasonal variation and management of *ngitili* on vegetation physical attributes are presented in Fig. 1. Fig. 1a revealed that above-ground herbaceous biomass was significantly higher in the rainy season than in dry season for the communal ($P=0.01$) and for the private *ngitili* ($P=0.01$). However, in the dry season, no significant

Table 1
Chemical composition and in vitro digestibility of key forage species sampled from communal and private *ngitili* in two consecutive seasons in Meatu District.

Species by season		Chemical composition and in vitro Digestibility (Mean in % of DM)						
Species	**Season**	CP	DM	ASH	NDF	ADF	InvDMD	InvOMD
Acacia nilotica	Dry	11.27b	96.17a	7.21c	63.28d	34.92f	57.78a	53.95a
	Rainy	13.91a	96.23a	6.75cd	71.13c	40.33d	51.97b	50.93b
Acacia tortilis	Dry	12.27b	94.28c	6.31d	73.76c	42.12c	36.73d	34.82d
	Rainy	11.24b	94.85bc	13.58a	75.02bc	43.95c	34.49d	26.32e
Bothriocloa isculpta	Dry	3.57d	94.56c	10.41b	77.55ab	37.75e	37.44d	40.15c
	Rainy	8.77c	95.21b	7.16c	68.63d	37.75e	49.13b	53.21ab
Cynodon nlemfuensis	Dry	4.46d	94.73c	6.87 cd	77.61ab	43.58c	30.51e	29.97e
	Rainy	7.94c	94.87bc	10.41b	75.96b	48.07b	43.59c	41.57c
Eragrostis tenuifolia	Dry	4.01d	94.52c	7.65c	79.54a	52.88a	39.22d	40.77c
	Rainy	10.70b	94.64bc	8.95c	73.31c	39.80d	50.04b	52.47ab
Species by ngitili management								
Species	**Management**							
Acacia nilotica	Communal	12.39a	96.22a	7.26c	69.77c	38.87c	51.85b	50.87ab
	Private	12.79a	96.18a	6.70c	64.64d	36.38d	57.90a	54.01a
Acacia tortilis	Communal	11.89a	93.67c	8.86b	77.66a	46.88a	24.11 f	18.92e
	Private	11.75a	95.46b	11.03a	70.91c	38.83c	47.11c	42.22c
Bothriocloa isculpta	Communal	6.52bc	95.14b	6.43c	72.61c	36.16d	43.95c	47.19bc
	Private	5.83c	94.64b	11.14a	73.56bc	39.34c	42.63 cd	46.16bc
Cynodon nlemfuensis	Communal	5.53c	94.84b	10.09a	78.64a	48.36a	34.33e	30.40d
	Private	6.87bc	94.77b	7.19c	74.93b	43.28b	39.78d	41.15c
Eragrostis tenuifolia	Communal	7.87b	94.49b	6.61c	76.11a	46.29a	45.33c	49.01b
	Private	6.83bc	94.68b	9.99b	76.74a	46.39a	43.94c	44.23c
Standard error		0.41	0.21	0.46	0.6	0.63	1.19	1.71
Significance levels								
Species		0.01	0.01	0.01	0.01	0.01	0.01	0.01
Management		0.92	0.04	0.01	0.01	0.01	0.01	0.01
Season		0.01	0.03	0.01	0.02	0.39	0.01	0.01
Species × season		0.01	0.49	0.01	0.01	0.01	0.01	0.01
Species × management		0.05	0.01	0.01	0.01	0.01	0.01	0.01

The least square means with different letters within the column denoted significant difference at $P\leq0.05$.

variation in above-ground herbaceous biomass observed between private and communal *ngitili* ($P=0.76$), but higher biomass was found in the private *ngitili* than in the communal *ngitili* during the rainy season ($P=0.01$). Likewise, BD was significantly higher in the rainy season than in the dry season (Fig. 1b) for both communal ($P=0.01$) and private *ngitili* ($P=0.01$). Moreover, significant higher BD observed in the private *ngitili* than in the communal *ngitili* during the rainy season ($P=0.01$). In Fig. 1c the lsmeans for SH, were significantly higher in the rainy season than dry season for both communal ($P=0.01$) and private *ngitili* ($P=0.01$).

3.3. Behavior of cattle and goats at pasture

In average animals found to spend more than 70% of their total time on pasture for foraging (grazing and/or browsing) in both seasons, where less than 30% of total time was spent for walking, ruminating, idling and other activities (Table 2). In general cattle spent considerable more time grazing than goats ($P=0.01$), but goats spent more time browsing than cattle ($P=0.01$). These two species behaved differently on pasture in terms of grazing and browsing between communal and private *ngitili* and between dry and rainy season (Fig. 2). The interaction between *ngitili* management and animal species (Fig. 2a) revealed no significant variation in grazing time by cattle, but goats spent significant more time grazing in private *ngitili* than in communal *ngitili* ($P=0.01$) and more time browsing in communal *ngitili* than in private *ngitili* ($P=0.01$). Other activities such as ruminating, walking and idling were independent of *ngitili* management, animal species and their interaction ($P>0.05$).

Although, scan observation did not shown influence of season on foraging activities (Table 2), focal observation in Fig. 2b revealed that cattle spent significantly more time grazing in rainy season than in dry season ($P=0.01$) and goats spent significantly more time browsing during rainy season than dry season ($P=0.01$). Both focal and scan observation indicated that time spent for other activities such as walking, ruminating and idling were significantly higher in the dry season than in the rainy season ($P>0.05$). Fig. 2b indicates that goats spent considerably more time walking, ruminating and idling during dry season, but seasonal variation found to have no significant effect on cattle in terms of walking, ruminating and idling. Seasonal variation appeared to have a significant influence on patch selection with highest number of patches visited in "Dry-Communal" and the least number of patches visited in "Rainy-Private" (Fig. 3a).

Both focal and scan observations indicated that variations in times of day had no significant effect on grazing ($P>0.05$). Nevertheless, focal animals found to spend significant more time browsing at early hours (AM) on pasture ($P=0.03$). Although, focal observation revealed no significant effect of time of day on other activities such as walking ($P=0.2$), ruminating ($P=0.67$) and idling ($P=0.24$), scan observation on the other hand indicated that, significant high number of animals walk and ruminate more in the late hours of day but were found to be more idle in early hours of day (Table 2).

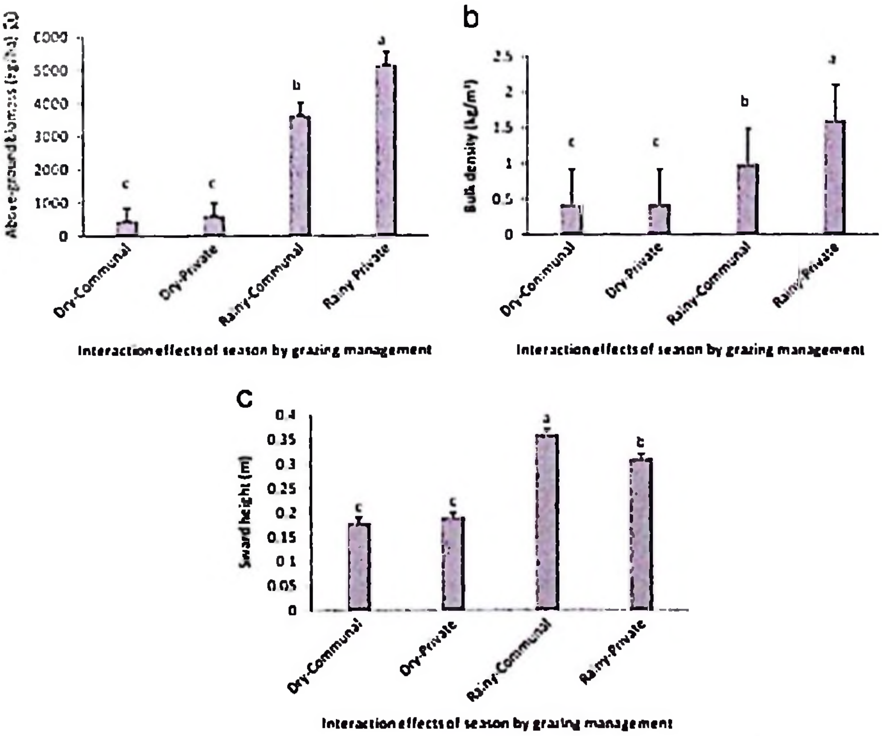

Fig. 1. The interaction effects of season by *ngitili* management on above-ground herbaceous biomass (a), bulk density (b) and sward height (c). Different letters indicate significant difference at $P\leq0.05$.

Table 2
Behavioral activities of cattle and goats in relation to season and *ngitili* management. The lsmeans ± SE estimated based on data from scan observation technique.

Variables	Mean estimated time (%)					
	Grazing	Browsing	Walking	Ruminating	Idling	Others
Season						
Dry	67.29 ± 1.84	9.48 ± 1.37	15.28 ± 1.33	4.81 ± 0.62	2.51 ± 0.58	0.67 ± 0.23
Rainy	68.77 ± 1.84	15.73 ± 1.37	10.32 ± 1.33	2.19 ± 0.62	1.63 ± 0.58	1.27 ± 0.23
Management						
Communal	70.71 ± 1.97	10.87 ± 1.42	12.21 ± 1.36	3.96 ± 0.85	1.38 ± 0.66	0.78 ± 0.23
Private	65.34 ± 1.97	14.34 ± 1.42	13.39 ± 1.36	3.05 ± 0.85	2.75 ± 0.66	1.15 ± 0.23
Time of day						
AM	68.55 ± 1.84	13.22 ± 1.37	11.45 ± 1.33	3.15 ± 0.62	2.45 ± 0.58	1.07 ± 0.23
PM	67.51 ± 1.84	11.90 ± 1.37	14.14 ± 1.33	3.85 ± 0.62	1.68 ± 0.58	0.87 ± 0.23
Season × management						
Dry-Communal	73.25 ± 0.21^{a}	5.88 ± 0.48^{c}	13.64 ± 0.45^{b}	5.77 ± 0.87^{a}	1.07 ± 0.66^{b}	0.42 ± 0.28^{b}
Dry-Private	61.33 ± 0.21^{c}	13.08 ± 0.48^{b}	16.91 ± 0.45^{a}	3.86 ± 0.87^{ab}	3.93 ± 0.66^{a}	0.92 ± 0.28^{ab}
Rainy-Communal	68.18 ± 0.21^{b}	15.86 ± 0.48^{a}	10.77 ± 0.45^{c}	2.16 ± 0.87^{c}	1.69 ± 0.66^{b}	1.14 ± 0.28^{ab}
Rainy-Private	69.36 ± 0.21^{b}	15.59 ± 0.48^{a}	9.87 ± 0.45^{c}	2.23 ± 0.87^{bc}	1.56 ± 0.66^{b}	1.39 ± 0.28^{a}
Significance levels						
Season	0.15	0.01	0.01	0.01	0.01	0.01
Management	0.01	0.01	0.21	0.44	0.01	0.12
Time of day	0.32	0.03	0.01	0.01	0.01	0.41
Season × Management	0.01	0.01	0.01	0.01	0.01	0.59

The least square means with different letters within the column denoted significant difference at $P \leq 0.05$.

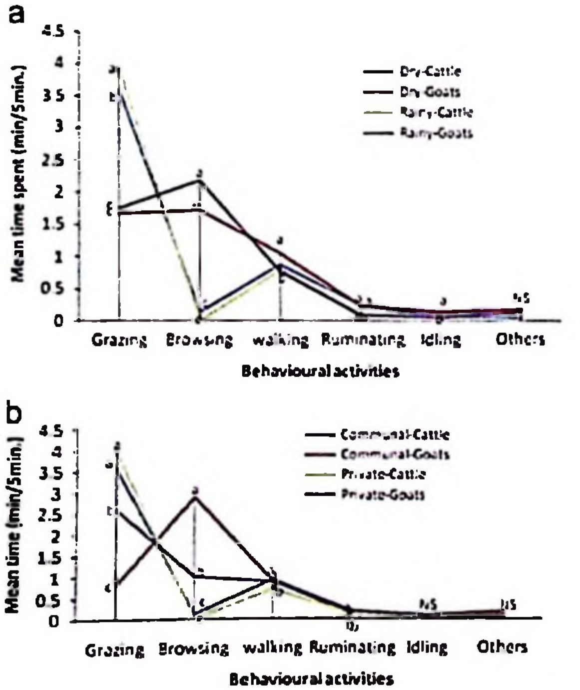

Fig. 2. Interaction effects of (a) season by animal species and (b) ngitili management by animal species on behavioral activities of cattle and goats on natural pasture. Different letters within the column line in the chart indicate significant difference at $P \leq 0.05$.

The results for main forage species eaten by focal animals are presented in Fig. 4. Out of 32 forage species recorded during observation, six species plus crop residues were most frequently eaten and thus categorized as main forage species. These main species were *A. nilotica*, *A. tortilis*, *B. insculpta*, *C. nlemfuensis*, *E. tenuifolia*, *U. mosambicensis* and crop residues (mainly maize stover and rice straws). Generally, cattle observed to eat more grasses while goats were found to eat more browses.

Interaction of season by animal species found to have significant influence on eating scores of forage species (Fig. 4a). Eating scores of cattle for *E. tenuifolia* and *U. mosambicensis* were significantly higher in the rainy season than in the dry season ($P < 0.05$), but season had no significant effects on eating scores for *B. insculpta*, *C. nlemfuensis* ($P > 0.05$). On the other hand goats found to have high significant preference for *A. tortilis* to *A. nilotica*; however, there were no significant differences in eating scores within species between dry and rainy season ($P > 0.05$). Both cattle and goats were found to forage crop residues most frequently in dry season than in rainy season (Fig. 4a).

Cattle and goats differ significantly in terms of forage selectivity between private and communal *ngitili* (Fig. 4b). Cattle eating scores for *E. tenuifolia*, *U. mosambicensis*, *A. nilotica* and *A. tortilis* did not vary significantly between private and communal *ngitili* ($P > 0.05$), but goats found to forage *E. tenuifolia*, *U. mosambicensis* and *A. nilotica* most frequently in the private *ngitili* and *A. tortilis* in the communal *ngitili* ($P < 0.05$). Both cattle and goats found to forage crop residues most frequently in the communal *ngitili* than in the private *ngitili*.

4. Discussion

Grazing is a complex interaction between animal, season, and environment (Baumont et al., 2004).

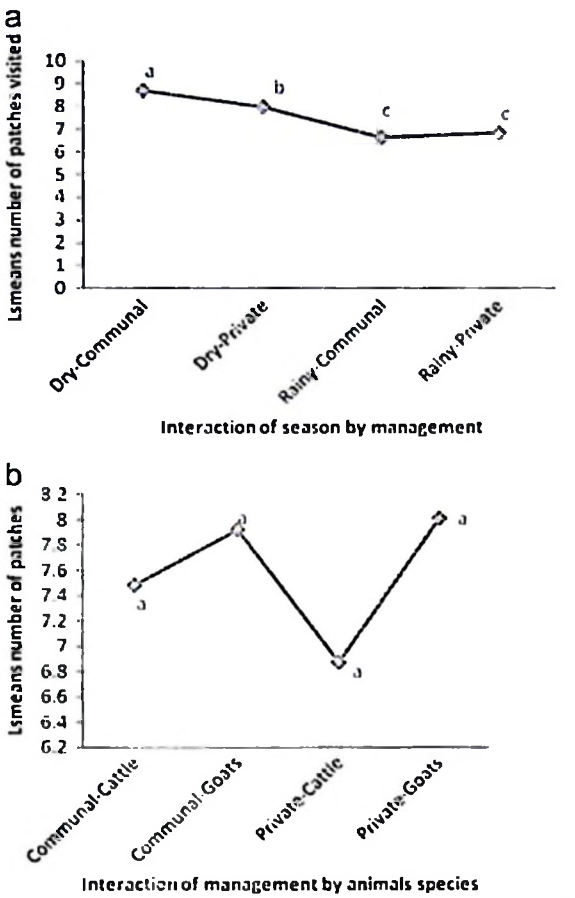

Fig. 3. Interaction effects of season by *ngitili* management (a) and ngitili management by animal species (b) on number of patches animals visited on natural pasture. Different letters indicate significance difference at $P \leq 0.05$.

Environment determines the forage available to the animal, while season affects the quality and quantity of that forage (Kassilly, 2002). This study revealed that both season and *ngitili* grazing management had significant impacts on the quality and quantity of forage. Variation in forage quality and quantity between the rainy and dry season is associated with seasonal responses to vegetation growth due to changes in soil moisture (Kassilly, 2002). Moreover, the differences in vegetation characteristics between private and communal *ngitili* might probably attributed with differences in ownership and types of management as described previously in method section. Furthermore, these differences in vegetation characteristics are most likely causing the changes in grazing behavior of cattle and goats between seasons and between *ngitili* management.

In Tanzania, as in many other African semi-arid environments, cattle are grazed together with small ruminants, such as goats and sheep. The strategies adopted by these animal species to survive together in heterogeneous environment, with high variation in quality and quantity of forage species, differ greatly. Observed high frequency grazing on poor quality grasses and crop residues by cattle can be associated with their physiological and morphological adaptation for utilization of fibrous feeds. According to Rook et al. (2004) these animals have relatively large gut capacity in relation to their metabolic requirements and thus are able to digest fibrous feeds efficiently. On the other hand, small ruminants such as goats require relatively more energy than large ruminants and thus have to select high quality feeds (Rook et al., 2004). In the present study, goats' browse preference probably allows them to select high quality plants that were highly digestible. Their preference for woody browses observed in the present study was consistent with findings from previous study by Osoro et al. (2012) and Sanon et al. (2007). Woody browses such as acacia species have high nutritive values but also have high levels of secondary chemical compounds (Rubanza et al., 2007). However, goats, like many other browsers, are able tolerate and metabolize toxic chemical substances such as phenolic compounds to less toxic derivatives. This is because the saliva of these browsers contains the amino acid *proline* that neutralizes the effects of phenolic compounds (Hoven, 2010).

Difference in selectivity observed between cattle and goats is an important adaptation strategy for reducing inter-specific competition in the condition where forage resources are scarce. This adaptation allows them to coexist in heterogeneous pasture because of resources partitioning (McNaughton and Georgiadis, 1986) and thus facilitate to effective range management. Tradition grazing management with mixed herd of cattle and goats on natural pasture appears to be productive; however in acute shortage of forage, extensive dietary overlap is more pronounced and increase inter-specific competition (Animut and Goetsch, 2008). For that matter, other management strategies such as use of tree-fodder supplements and treatment of crop residues need to be investigated.

Despite the fact that, animals select forage species of the highest quality available at any point in time (Sebata and Ndlovu, 2012), animal eating preference is also a function of the availability of that forage species (Fehmi et al., 2002). Although, *B. insculpta*, *C. nlemfuensis*, and *E. tenuifolia* had lower CP content and relatively high NDF, they were eaten fairly in large proportions probably because they were highly abundant in the study area. According to Baumont et al. (2000), animal may trade off quality for quantity and switch to less preferred species to save energy and time cost for searching high quality species. Indeed, feed selection is not only determined by forage preferences associated with quality of such feed, but also by its availability and cost involved in gathering the feeds (Distel et al., 1995). This is one of the most important strategies for animals grazing in natural pasture to balance the equilibrium between energy offered and energy expenditure. Lachica and Aguilera (2005) pointed out that, energy expenditure associated with locomotion causes huge increases in total energy requirements of animals in natural pasture.

The most important and substantive results were the significant variations in physical characteristics of vegetation and their chemical composition between rainy and dry season which is most likely associated with notable changes in foraging time and eating preference of cattle

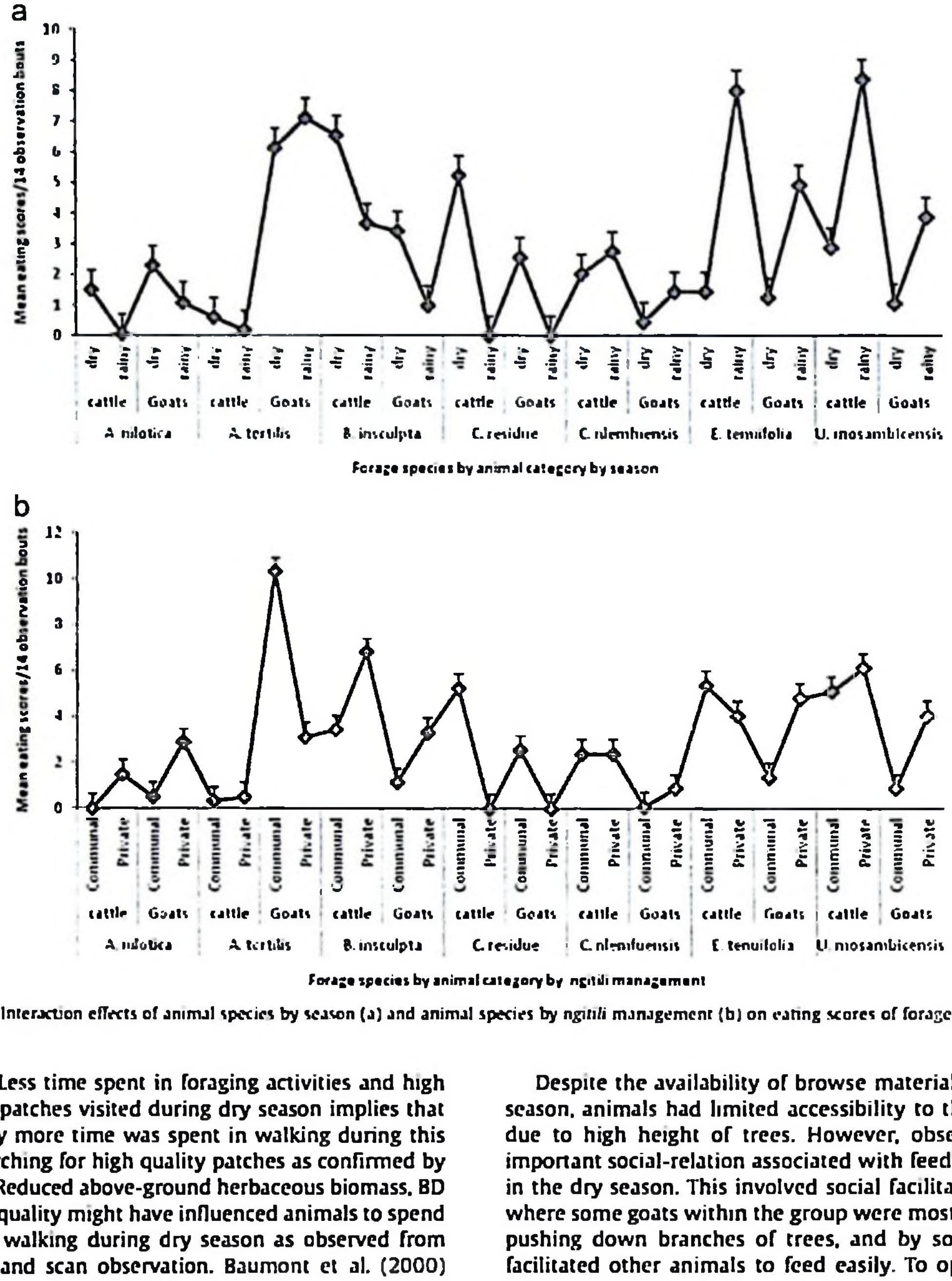

Fig. 4. Interaction effects of animal species by season (a) and animal species by *ngitili* management (b) on eating scores of forage species.

and goats. Less time spent in foraging activities and high number of patches visited during dry season implies that significantly more time was spent in walking during this season searching for high quality patches as confirmed by this study. Reduced above-ground herbaceous biomass, BD and forage quality might have influenced animals to spend more time walking during dry season as observed from both focal and scan observation. Baumont et al. (2000) noted that forage depletion in a patch motivates an animal to move on to the next patch. Poor forage quality may have a considerable influence on changes in feeding behavior of pasture feeding animals (Ngwa et al., 2000). Therefore, combined effects due to physical characteristics and quality of forages may affect animals decision on patch selection (Piasentier et al., 2007), but other factors, such as distance to water, need for shelter, and social factors, may also influence patch preference. In addition, patch selection can also be enhanced through variability caused by urination and defecation (Jaramillo and Detling, 1992).

Despite the availability of browse materials in the dry season, animals had limited accessibility to those forages due to high height of trees. However, observers noted important social-relation associated with feeding behavior in the dry season. This involved social facilitation feeding where some goats within the group were most often noted pushing down branches of trees, and by so doing they facilitated other animals to feed easily. To optimize feed intake in the dry season when forage is scarce, herders may apply this facilitation strategy (which is non-destructive to the vegetations) to feed their animals. A long stick with hook at the end can be used to pull down branches of trees to facilitate animals' accessibility to browsable materials.

Moreover, animals spending considerably higher time, ruminating in the dry season than in the rainy season, suggest a low quality forage DM intake. Animals feed on poor quality diet required more time to ruminate as a way to breakdown feed components (Gregorini et al., 2012). In this season most of forage species were matured, with high proportion of stems and leaves of high tensile strength. In addition, crop residues such as maize stover with high cell wall contents were frequently eaten in the dry season. The characteristics of these forage probably influenced animals to spend substantial higher time ruminating to reduce feed particle size. Wenninger and Shipley (2000) found that rumination time was positively correlated with NDF contents. These authors argued that, in addition to microbial activities in the rumen, rumination play important role in reduction of feed particles size. However, non-variation in ruminating time between cattle (that were mainly grazed on grasses) and goats (browsing on woody species) was contrary to the findings of Rutter et al. (2002) who reported substantial higher rumination time in grass-fed animals. This anomalous behavior might be explained by dietary overlap between cattle and goats observed during dry season. Due to lack of high quality forage in the dry season, goats frequently found to eat low quality diet such as crop residues and *B. isculpta* that most likely made them to spend more time ruminating.

In addition to the effects of season on animal behavior, variation in physical vegetation attributes between private and communal *ngitili* had more pronounced effect on goats foraging behavior than cattle. This might also be associated with physiological and morphological adaptation of these two animal species. Since adaptation of cattle enables efficient utilization of roughages and therefore changes in quality of feeds may not have significant variation in their feeding behavior. They are capable to retain feeds longer in the rumen than goats and that facilitates complete digestion of cellulose and other structural carbohydrates (Rook et al., 2004). On the other hand, goats are selective feeders (Van Soest, 1996), and a slight change in quality of feeds may alter their foraging behavior. They tended to spend more time grazing in private *ngitili* and more time browsing in communal *ngitili*. High abundance of herbaceous vegetation in the private *ngitili* may have increased the chance of goats to get high quality feeds through grazing but depletion in above-ground herbaceous biomass in the communal *ngitili* probably influenced goats to select available woody browses. Although, chemical composition of key forage species revealed non-significant differences between private and communal *ngitili* but, the heights of herbaceous layer were relatively higher in the communal *ngitili*, which may reflect depletion of forage quality. Hirata et al. (2006) pointed out that, taller herbages are usually poor in quality due to high proportions of matured leaves to young leaves.

Lack of variation in grazing duration for cattle in relation to the time of day was contrary to the previous studies of cattle grazing on natural pasture (Orr et al., 2001; Rutter et al., 2002). Higher rate of feeding frequencies have been noted in cattle under continuous feeding condition in the evening than in the morning (Orr et al., 1997; Rutter et al., 2002). However, Gregorini et al. (2009) reported that under condition of unrestricted to pasture, cattle may not have big diurnal fluctuations in feeding behavior. Nevertheless, the behavior of goats spending considerable more time browsing in the early hours of day was consistent to the findings of Goetsch et al. (2010) who reported that the west African dwarf goats grazing intensively after morning releases on pasture than in the evening. The authors argued that, less feeding in the evening times may be due to "prior selection of more palatable dietary components in the morning and thus partial satiation facilitates greater selectivity in late hours". This argument may be valid because in the present study goats spent substantial higher time walking in the evening.

Previous studies have noted that ambient temperature has marked effects on grazing behavior (Taweel et al., 2006; Tucker et al., 2008). The ambient temperatures recording during the study period may not have exceeded thermo-neutral zones of grazing animals to the extent of causing significant differences in grazing behavior, as explained by Huber et al. (2008). Furthermore, the physiological state of grazing animals, such as lactation, significantly affects grazing behavior (Gibb et al., 1999), due to greater nutritional requirements. In our study, focal animals were neither lactating nor pregnant, and therefore the changes in the behavioral activities of cattle and goats were most likely result of seasonal fluctuations in the quality and quantity of forages, *ngitili* management, and the inherent adaptations of animal species.

5. Conclusion

In our study, the differences in feeding habits between dry and rainy season probably associated with seasonal variation in quality and quantity of forages. Observed variations in behavioral activities between cattle and goats within and between seasons might be attributed with inherent physiological and morphological adaptations of these two animal species. Variation in the physical vegetation characteristics in relation to the types of grazing management might have contributed to observed differences in foraging behavior of cattle and goats between private and communal *ngitili*. The reduction in forage quantity in communal *ngitili* had marked effects on goats foraging behavior but had no significant effects on feeding behavior of cattle. Whereas, stocking animals in mixed herd on natural pasture appears to be beneficial due to their variations in foraging habits that resulted in resources partitioning, other feeding facilitation strategies should be investigated to optimize feeding intake especially in acute shortage of forage. Looping branches of trees, use of treated crop residues and supplementation with fodder tree leaves meals are some of strategies that need further investigations.

Conflict of interest statement

Authors have no conflict of interest regarding this submitted manuscript.

Acknowledgments

The field work was financially supported by the Norwegian Government through the Programme for Agricultural and Natural resources Transformation for Improved Livelihoods (PANTIL). Authors would like to thank the staff members of the Department of Animal Science and

Production at Sokoine University of Agriculture (SUA) for their help in identification of some plant species.

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PAPER 3

Concentrate supplementation: effects on growth performance and behavioral activities of cattle grazed on natural pasture.

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Abstract: The study was conducted in the Hanang district, Manyara, to determine the effect of concentrate supplementation on growth performance and foraging behavior of Zebu cattle grazing on natural pasture. Twenty Zebu steers were studied within two years: 2012 (n = 8) and 2013 (n = 12) and were distributed equally into two dietary groups: pasture + concentrate (PS) and natural pasture alone (NP). Animals in the PS group were offered concentrate mixture daily, and were allowed to graze freely on natural pasture together with those in the NP group. The animals' body weights were estimated every two weeks and body conditions scored in the last week of feeding trial. The focal observation technique was used to determine animal grazing behavior where the Official Analytical Chemists procedure (AOAC) was used to determine chemical composition of key forage species. The average daily gain (ADG) was significantly higher ($P \leq 0.05$) in the PS group than in the NP group. Significant less time ($P \leq 0.05$) was spent in feeding by animals in the PS group than those in the NP group. Times spent for walking, standing/ruminating, lying/ruminating and idling were significantly higher ($P \leq 0.05$) in the PS group than in the NP group. Significant less bite rates ($P \leq 0.05$) were also observed in the PS group than in the NP group. The most highly abundant forage species such as nut grass *(Cyperus rotundus)*, creeping bluegrass *(Bothriochloa insculpta)* and African stargrass *(Cynodon nlemfuensis)* exhibited low CP content and in *vitro* dry matter digestibility but were most frequently eaten by the focal animals. Strategic supplementation with locally

available and affordable concentrates is recommended for profitable ruminant productivity and for sustaining environmentally friendly grazing strategy.

Keywords: Agro-pastoralists, Behavior, Grazing, Growth performance, Natural Pasture

1.0 Introduction

More than 90 % of livestock in Tanzania belongs to traditional pastoralists and agro-pastoralists and are mostly grazed on communal semi-arid rangelands. These rangelands cover more than 74 % of total land area of about 88.6 million hectares (Mwilawa et al. 2008). Livestock production in these rangelands is limited by scarcity of forage resources. According to Mtengeti et al. (2008), lack of forage in terms of quantity and quality during dry season is one of the most important constraints to ruminant production in Tanzania. Persistent drought and excessive livestock grazing have adversely affected rangeland resources by diminishing the quality and quantity of forage (Kamwenda 2002). The forage resources are characterized by seasonal variation in quantity and quality. Availability of high quality forage remains for a short period of the rainy season and cattle are frequently exposed to periods of prolonged under-nutrition in the dry seasons which seriously impairs their productivity (Kakengi et al. 2001). Generally, the rainfall in Tanzania is low and unpredictable and the country is characterized by prolonged drought (Madulu 2003).

Pastoralists and agro-pastoralists in the northern part of Tanzania particularly in the Manyara region are constrained with shortage of forage due to increased livestock populations and an expansion of crop production. According to the Nation Bureau of Statistics (NBS) report, the region is highly populated with about 3.9 million ruminant livestock of different species (NBS 2012). It is the region with third highest density of livestock in the country after Shinyanga region (6.4 million livestock) and Arusha region (5.1 million livestock). The region has about 1.6 million cattle, 1.5 million goats and 0.6 million sheep (NBS 2012). The indigenous East Africa Short Horn Zebu cattle (*Bos inducus*) and the Small East Africa goats are the main local breeds kept in Manyara region (Sieff 1997). Cattle have highest economic and social value of all livestock among the *Barabaig* pastoralists in this region and are used mainly as sources of protein (meat and milk), provide monetary income and provision of dowry during marriage, and hides are used for clothing, while their dung are used as building materials (Sieff 1999).

The expansion of wheat production in Manyara region has resulted in massive loss of grazing lands. For example, more than 40,000 acres of productive grazing lands in the Hanang district were set aside for wheat production scheme since 1968, under the parastatal National Agriculture and Food Cooperation (NAFCO) funded by the Canadian International Development Agency (CIDA) (Lane 1994). Later on it was reported that the farms expanded and their total size amounted to 100,000 acres, and as a consequence, the *Barabaig* herders were evicted and forbidden crossing the boundaries of this farm (Fratkin 1997). Shrinkage of grazing lands contributed to change in the grazing management from the previously strategy of rotational resting to more intensive grazing regime and resulted in the decline of quality and quantity of the pasture. Increased soil compaction, decline of perennial grasses and increased annual herbs in the pasture have been attributed to the heavy grazing in this region (Lane 1990).

Currently, social concern about maintenance and restoration of degraded rangeland resources has gained momentum in African dry lands. The idea of keeping stock number at acceptable ecological carrying capacity has gained recent motivation as one useful strategy for halting rangeland degradation (Campbell et al. 2000; Morton & Barton 2002). However, destocking has received strong criticism as an ineffective way of restoring the degraded rangelands (Hary et al. 1996). This is due to the assumption that animals number and vegetation dynamics are independent of one another (Hein 2006). Change in vegetation composition and biomass in semi-arid rangelands are believed to be related to unpredictable rainfall rather than heavy grazing pressure (Vetter 2005). Moreover, pastoralists' resistance to reduce stock size may be because these animals are not only considered as sources of food but play other vital roles in society, as means of transport, draught power and emotive values (Salem & Smith 2008).

Effective management of grazing animals requires adequate knowledge on the influence of animals on the pasture and environment and vice versa (Kassilly 2002). Animal behavior and productivity are closely related and thus knowledge of behavior of grazing animals is an important for understanding their productive performance (Kassilly 2002). An understanding of grazing behavior and growth performance of ruminants on natural pasture is practically important for both as an environmentally friendly management strategy and for profitable ruminant production (Sanon et al. 2007). It was therefore assumed that cattle grazed on natural pasture and supplemented with concentrate would result in higher growth rate and reduced grazing intensity on pasture lands compared to those grazed on pasture alone. However, information on growth performance and behavioral activities of Zebu cattle grazing on natural pasture with access to concentrate supplementation is lacking in Tanzania. Such information would be useful for profitable ruminant production and rangeland management. This paper presents the results of the study carried out in Manyara region within the Haydom Farm and Development Ltd. and highlights the importance of concentrate supplementation on the growth performance and behavioral activities of Zebu cattle fed on concentrate plus pasture against those grazed on natural pasture alone.

2.0 Materials and methods

2.1 Study area

The study was conducted in a 111.6 acres grazing plot within the Haydom Farm and Development Ltd. in the Hanang District, Manyara region. The farm is situated at 35°12'E and 04°25'S. This area has semi-arid climate with annual rainfall ranging from 408 to 802 mm and temperatures range from 20° to 30°C (Safari et al. 2011). The area is characterized by black cracking clay soil and the vegetation type is mainly wooded grassland dominated by Acacia species. The main herbaceous plant species dominating the study area are creeping bluegrass *(Bothriochloa insculpta)*, nut grass *(Cyperus rotundus)*, Indgofera *(Indigofera indica)*, sabi grass *(Urochloa mosambicensis)*, devil's thorn *(Tribulus terrestris)* and *Oxygonum sinuatum*. The Hanang district is inhabited by two main tribes: the *Iraqw* and the *Barabaig*. Most of *Iraqw* are subsistence farmers with maize as main staple food while the *Barabaig* are agro-pastoralists with cattle and goats as major livestock species (Winkler et al. 2010).

2.2 Sampling procedures

2.2.1 Experimental design

The study was conducted for two consecutive dry seasons in 2012 and 2013. In 2012, eight Zebu steers were selected from agro-pastoralists near the Haydom Farm and Development Ltd. and were distributed equally into two dietary groups: pasture + concentrate (PS) and natural pasture grazed alone (NP) with respective average initial weight of 211 and 200 kg. In 2013, twelve steers belonging to the Haydom Farm and Development Ltd were used for behavior study. Like in 2012, these steers were distributed equally into the PS group and the NP group. It was not easy to track the ages of individual animals due to poor record keeping, but selected steers in both years were estimated to be about three to four years old. All studied steers were non-castrated, never used as draft power animals and no physical abnormalities were observed.

Studied animals were de-wormed and ear-tagged before starting the experiment. Animals in the PS group were supplemented with concentrate for 90 days in 2012 and 60 days in 2013. The concentrate mixture was formulated from maize bran (70 %), sunflower seed cake (27 %), mixed mineral (2 %) and salt (1%). The concentrate supplements was offered daily at 7.00 am (before animals' release to the pasture) and at 6.00 pm upon returning from pasture. Each animal was given approximately 2.34 kg DM in the morning and 2.34 kg DM in the evening. However, after residual collection, the average daily intake was estimated to be around 4 kg DM per day per animal. The NP group was not given concentrate and solely grazed on natural pasture. Both groups were herded together on natural pasture from 9.00 am to 5.00 pm every day. All studied animals in both years were grazed on the same grazing plot familiar to them.

2.2.2 Estimation of animal body condition and weight changes

All studied animals were monitored by recording their body weight and estimating body condition scores. Body weights were recorded for every two weeks using weigh-tape measuring from the girth of the chest immediately after elbows. An average daily gain (kg/day) of individual cattle was obtained by subtracting initial body weight (kg) from the final body weight (kg) and dividing by the number of experimental days. Body condition scores (BCS) were estimated in the last week of feeding trial using a five point scale adopted from Wildman et al. (1982). The scale ranges from 1 = very thin, 2 = thin, 3 = moderate, 4 = fat to 5 = very fat. The BCS were based on appearance and palpation of animal's back and hind-quarter. The scores of panel of four trained people were averaged and the mean score was considered to represent a body condition of a particular animal.

2.2.3 Forage sampling and estimation of species composition

Prior to behavioral observation the vegetation composition and sward height were estimated in the grazing plot. Within the grazing plot, two diagonal transect lines 500 m long were established. Along the transect line, a square quadrat (0.25 m X 0.25 m) was dropped at intervals of 20 m. The swards' height (SH) was measured within quadrat and all plant species within the quadrat were identified. The numbers of individual species in each quadrat were recorded. Unidentified species were sampled and taken to Sokoine University of Agriculture (SUA) for further identification. The key forage species (abundance and most frequently eaten) were sampled and taken to the laboratory of the Department of Animal Science and Production at SUA for chemical analyses.

2.2.4 Feeding behavior study

The behavioral activities of studied animals were determined on pasture using focal observation method (Lehner 1996). In both years, observation was initiated after one month adaptation period. Four observers were trained and accustomed with animals one month before observation. Observation was done in six consecutive days in each year and each observer was assigned to one focal animal per day to record time spent by focal animal for different behavioral activities. Behavioral activities were classified into feeding, walking, standing + ruminating, lying + ruminating, idling and other activities. An animal was considered to be idle when standing or lying without eating and/or ruminating. The category of other behavioral activities included playing, grooming, running, rubbing against trees and agonistic behavior.

Observation was done in 5 minutes per bout at an interval of 5 minutes between observation bouts. The estimated time spent by animals on pasture for each activity was based on assumption made by Kassilly (2002) that "the behavior of animals at the time of observation is representative of the interval between observations". Observation was conducted in two sessions every day: from 9:00 am to 12:00 am and from 2:00 pm to 5:00 pm. To avoid bias due to systematic error, observers were not informed about treatment groups (PS vis. NP) and were switched to another focal animal every next day. Alongside behavioral activities, observers also recorded number of patches visited and number of bites attained by each focal animal in each 5-minute observation bout. A patch was taken as a spatial aggregation of bites over which instantaneous intake rates (IIR) remained constant (Baumont et al. 2000). This is the area on which animal initiates and terminates foraging sequence before reorienting to another location (Jiang & Hudson 1993). Bite was considered as head movement associated with gripping a bunch of herbage in the mouth (Avondo et al. 1995) or an act of breaking off one or more pieces of forage from parent plant or picking it up from the ground (Kassilly 2002). Since observers were accustomed to animals, they were able to keep close to the focal animals (1-2 m away) to track the number of patches and count the number of bites per observation bout. Although it was not possible to count the number of bites per individual plant species, observers were able to identify types of plant species eaten in every observation bout.

2.2.5 Chemical analyses of forage samples

Five key forage species sampled from the natural pasture were chemically analyzed in the Department of Animal Science and Production laboratory. All samples were oven-dried at

105°C temperature, ground and filtered through 2 mm sieve, packed and labeled. Chemical composition of feed samples were analyzed following the AOAC (1984) procedures for moisture content, dry matter (DM), ash, and crude protein (CP). Neutral and acid detergent fiber (NDF and ADF) were analyzed by the method of Van Soest and Robertson (1991). *In vitro* dry matter digestibility (INVDMD) and organic matter digestibility (INVOMD) were determined using the two-stage techniques of Tilley and Terry (1963).

2.2.6 Statistical analyses

Data obtained were subjected to analysis of variance using proc mixed model of SAS (2004). For the average daily gain (ADG) and body condition scores (BCS) the following model was used: y (ADG and BCS) = Feeding duration (90 or 60days) + Dietary treatment (PS or NP) + Feeding duration*Dietary treatment + Residual. The model used for behavioral study was y (time spent for feeding, walking, standing/ruminating, lying/ruminating, idling and others activities; number of patches and bite rates) = Feeding duration (90 or 60days) + Dietary treatment + Time of day (AM or PM) + Dietary treatment•Time of day + Days (year) + Observers (4 observers) + Residual. Both Observers and Days were taken as random independently distributed variables. The Residual was assumed to have auto-regression (AR1) within individual animals (ID) and time of day. Least square means (lsmeans) differences were tested with F-test.

3.0 Results

3.1 Body weight and body condition

The changes in live body weights of supplemented and non-supplemented Zebu steers are presented in Figure 1 and 2. The weight gain was significantly affected by supplementation, ADG being 350g higher for animals in the PS group than those in the NP group ($P = 0.02$). The ADG was also found to vary significantly with feeding duration (Fig. 1), being twice as much in animals finished for 60 days in 2013 compared to those finished for 90 days in 2012 ($P = 0.003$). The one-way interaction of dietary treatment and finishing duration was found to have no significant effect on weight gain ($P > 0.05$). The weight for both supplemented and non-supplemented groups were found to increase progressively as indicated in Figure 2. Neither dietary treatment nor feeding duration had influence on the estimated body condition scores ($P > 0.05$).

3.2 Herbaceous species composition and chemical composition of key forage species

Vegetation type in the grazing plot was characterized by wooded grassland dominated with herbaceous cover and scattered woody species. The mean estimated height for herbaceous vegetation cover was 20.4 ± 1.69 cm. The herbaceous vegetation composition was dominated by *B. insculpta, C. rotundus*, masai love grass *(Eragrostis tenuifolia), I. indica, O. sinuatum and T. terrestris* (Figure 5). Large variation in chemical composition and *in vitro* digestibility of the key plant species were observed in which *B. insculpta, C. nlemfuensis* and *C. rotundus* found to have relatively low CP contents and IVDMD level, but higher NDF (Table 1). However, *I. indica and T. terrestris* were found to have relatively higher CP content, INDMD and lower NDF (Table 1).

3.3 Feeding behaviour patterns

The time spent by animals on different activities on pasture was expressed as percentage of their total observation time (Table 2). Time spent for feeding was twice higher for animals in the NP group than those in the PS group. On average animals grazed on natural pasture alone spent more than half of their total time on pasture for feeding. They had significant higher bite rate than those observed in the PS group (Fig. 4b). On the other hand, supplemented animals were found to have visited considerably more patches than those visited by animals in the NP group (Fig. 4a).

Animals in the PS group were found to have significantly more time spent for walking on pasture than those in the NP group (Tabe 2). They were observed to walk from one patch to the next selecting forage species of their preferences. Movements of the herd toward the preferred patches within the pasture were initiated and terminated by one or two leading animals within the group. Forage species most frequently eaten by animals were *C. rotundus, B. insculpta, T. terrestris, C. nlemfuensis, O. sinuatum* and *U. mosambicensis* (Figure 5). The eating frequencies for most of these species were found to be closely related to the frequencies of their occurence (Figure 5). However, eating frequencies of some few species such as *C. nlemfuensis, Euphorbia hirta* and *Tagetes minuta* were not related to their occurence.

Time spent for other activities such as standing/ruminating, lying/ruminating and idling were also found to differ significantly between the two groups, being higher in the PS group than the NP group (Table 2). Interaction effect of dietary treatment and time of day was found to have significant effects on time spent for walking, standing/ruminating and others behavioural activities (playing, grooming, running, rubbing against trees and agonistic behaviour). For example, time spent for walking was found to be almost significantly higher for supplemented animals in the morning (PS*AM) whereas the same group spent significantly more time for standing/ruminating at late hours (PS*PM) than other combinations of group and time of day (Fig. 3). The PS group also spent more time performing others activities such as playing, grooming, running, rubbing against trees and agonistic behaviour at early hours of the day (PS*AM). Neither bite rates nor number of patches were found to be influenced by the time of day.

4.0 Discussion

Availability and quality of forage are limiting factors for ruminant production in semi-arid rangelands. The low weight gain observed in animals grazed on pasture alone reflects poor quality of available forage species in the natural pasture especially in the dry season. Natural pasture in Tanzania are characterized by rapid decline in nutritive values during the dry seasons (Goromela et al. 1997). Animals grazed on these pasture resources lack important nutrients such as crude protein (CP) required for animal growth. According to McDonald et al. (2002), the recommended protein intake for growth requirements of cattle, body weight ranging from 200 to 400 kg should not be less than 15 % of DM intake. The chemical analyses of dominant grass species from pasture revealed too low CP levels (2 – 14 %) to meet necessary requirements for growth. These findings were in accordance to Anbarasu et al. (2004) and Dewhurst et al. (2003) who reported lower level of CP content and higher NDF of species from natural pasture than conventional concentrate mixture. Weights of supplemented animals increased progressively, but the mean ADG (0.95 kg/day) was below the normal range (1.66 to 1.79 kg/day) for cattle on a finishing diet (Meissner et al. 1995). This could be explained by variations in the breed types and production systems. Generally, indigenous cattle raised on a poor diet pasture exhibit low weight gain because they require substantial amount of energy for locomotion compared to stall fed animals. Muchenje et al. (2009) indicated that indigenous cattle breeds, such as Nguni and Zebu spend more energy walking long distance searching for high quality forage than other breeds. According to Lachica and Aguilera (2005), energy expenditure of grazing animals may dramatically exceed those of confined animals. Despite the fact that, the grazing plot in the present study was not very far, approximately 2 km away from the house, supplemented animals spent considerable more time for walking around searching for high quality pasture. Krysl and Hess (1993) found that energy cost for walking searching feed in the harsh environments can increase maintenance requirements from 10 to 25 % in grazing animals.

Weight gain has considerable economic effect on livestock production in Tanzania because animals are sold on the basis of their live weight. Although the mean weight gain per day for the PS group was 350g/day higher than the NP group, this did not cover the extra cost of production. For example the 4 kg of concentrate mixture consumed by each animal per day cost around Tsh. 1,450 (approximately 0.89 US dollar) while the price of 350g gain per day is about Tsh. 1,440 (0.88 US dollar). Therefore, the anticipated profits from concentrate supplementation may not be high, unless agro-pastoralists use their own locally produced milling by-products such as maize brain and sunflower seed cakes available after crop processing. Maize and sunflowers are produced in Tanzania as main staple crop and cash crop respectively (Birch-Thomsen et al. 2001; Hyman 1993), and a substantial amount of maize brain and sunflower seed cakes are available after the milling process. Alternatively, multipurpose trees such as *Leucaena leucocephala* (Kakengi et al. 2001) and *Moringa oleifera* (Sarwatt et al. 2002) can be used as cheap protein supplements in dry season when quality of forage declines.

In addition to nutrition, weight gain can be influenced by several other factors such as duration of finishing, age and type of breed (Owens et al. 1993). Since all experimental animals were local Zebu cattle (*Bos inducus*) and their age and initial weight was not known to vary significantly, the variations in weights gain are most likely coming from variation in dietary treatment and finishing duration. From the present study, it cannot be claimed that long finishing duration is economically worthwhile, since the higher weight gains were found in animals finished under 60 days compared to those under 90 days. The mean live gain was 590g/day lower for animal finished under 90 days than for those finished under 60 days. These findings are supported by Keane et al. (2006), who found that extending the duration of finishing period reduced mean daily live weight in beef steers finished on concentrate diet. The above authors associated low live weights in longer finishing time with poor body conformation due to disproportional increased in fatness.

The significantly higher time spent in feeding activities for animals grazed on pasture alone, compared to those supplemented with concentrate, is possibly related to the poor availability of quality forage. Poor availability of quality forage in the natural pasture dictates animals to spend more time feeding to optimize feed intake. Animals grazing on poor and heterogeneous pasture tend to spend more time organizing grazing process (Vallentine 2001). Kassilly (2002) maintained that in the poor forages, animals tend to feed at the expense of idling and ruminating. Huber et al. (2008) reported similar findings: that animals spent most of their pasture time budget on foraging and very little time spent to other activities. Since the availability and quality of forage is considerably reduced in the dry season, use of concentrate feed is critically important to maintain the ruminant production (Sanon et al. 2007). Krysl and Hess (1993) pointed out that concentrate supplementation does not only provide high energy protein to the animals but also decreased energy expenditure for grazing.

Similarly, the differences in bites per minutes observed for animals in the NP group against those in the PS group could be due to differences in nutrients intake between the two groups. Poor nutritive values of forage species from natural pasture might be the cause for animals in the NP group to have more bites in order to satisfy their nutrients requirements. The relatively higher bite rates and more grazing time spent by animals in the NP group on pasture, might reflect the degree of nutrient requirements needed to satisfy their satiation. An alternative explanation could be that inadequate forage resources in the natural pasture motivated animals in the NP group to continue feeding until the rumen space is full, because voluntary intake is also determined by rumen fill effect (Baumont et al. 2000). However, feed intake also depends on physical characteristics of forage. According to Kennedy (2007) physical characteristics of swards may affect forage intake of grazing animals. Hirata et al. (2006) pointed out that taller herbages consist of higher proportion of low-quality materials because of higher ratio of aged to young leaves or higher stem to leaf ratio.

On the other hand, the decreased feeding time coupled with lower number of bites per minutes observed for animals in the PS group may reflect the decrease in voluntary intake of poor quality roughages available on natural pasture following concentrate supplementation. These findings were in line with Lindström and Redbo (2000), who found that feeding duration and feed intake of cattle grazed on natural pasture decreased for animals supplemented with high levels of concentrates. The decrease in feed intake for the PS group on pasture may be explained with metabolic control as a result of high concentration of volatile fatty acid (VFA) in the rumen due to rapid fermentation of soluble concentrates. Baumont et al. (2000) showed that animals fed soluble fraction materials had more rapid fermentation which led to increased osmotic pressure due to concentration of VFA in the rumen, which in turn lowered feed intake.

Most importantly, these results concerning reduction in grazing time and bite rates following concentrate supplementation have some environmental implications. Cattle supplemented with high-energy concentrates appear to exert less pressure on herbaceous vegetation and this most likely lowers degradation of rangeland resources. Therefore, for maintenance and restoration of degraded rangeland resources, manipulation of grazing time through concentrate supplementation is essential, especially during the dry season. However, grazing pressure on natural pasture is a function of both grazing time and stocking rate (Hart et al. 1988). According to Vallentine (2001), cattle spend more time grazing as stocking rate increases. Consequently, more time spent on walking might be environmentally destructive due to soil compaction. Therefore, manipulation of grazing time should also consider the ecologically acceptable stocking rate as a fundamental aspect in range management.

More patches visited by animals in the PS group probably imply that supplementation has effect on animal selectivity. Tesfa et al. (1995) found that possibility of cattle to select plant materials of high nutritional value is enhanced by concentrates supplementation. On the contrary, hungry animals become less selective and visit fewer patches, and bite rate increases (Rook et al. 1994). Decrease in degree of selectivity causes animals to consume poorer quality diet and thus require more rumination. In the present study, animals in the NP group were observed to have low number of patches which reflect less selectivity and more utilization of lower quality diet. However, significant less time spent on rumination by this group was not expected. Since rumination time depends upon characteristics of feeds (Lindström & Redbo 2000), more rumination may be expected for animals fed on low quality diet to produce small particle size (Rook et al. 1994). Rumination time normally increases with increasing proportion of NDF and forages' particle size (Maekawa et al. 2002). This notable abnormal behavioral pattern may be associated with adapted behavior of cattle to optimize forage intake during the day time, and ruminate at night time when resting. Since cattle are diurnal ruminants they could probably maximize feed intake during the day time and spend the night time for rumination (Fehmi et al. 2002).

Selectivity of different plant species is influenced by spatial availability and quality of forage. This has been confirmed by this study where the eating frequencies of individual forages species were found to be highly influenced by their frequencies of occurrence or abundance. Despite the fact that *Bothriochloa insculpta* and *Cyperus rotundus* had poor quality, they were eaten in fairly large quantities, most likely because they were highly abundant. As high quality forage resources are often scarce and become depleted in the dry season, forage selection is assumed to be driven by their availability (Van Beest et al. 2010). It is not known why *Cynodon nlemfuensis* was eaten in a reasonable proportion despite its poor availability and low quality. *Euphorbia hirta* was also fairly abundant, but poorly or not eaten by grazing animals. The eating preferences for *Cynodon nlemfuensis* and avoidance of *Euphorbia hirta* might probably be due to previous learning experience of grazing animals. According to Launchbaugh and Howery (2005) the previous positive consequence increases the likelihood of the behavior being expressed in future, whereas aversive post-ingestive feedback decreases the future likelihood of the behavior.

5.0 Conclusion

The behavioral patterns observed may have important implications regarding the balance between ruminant productivity and rangeland management. Supplementation of cattle with high-energy concentrate has shown a positive effect on animal growth. Increases in weight gain within short time span and change of feeding behavior on natural pasture following concentrate supplementation may enhance cattle productivity and lower degradation of rangeland vegetation. For profitable ruminant production and environmentally friendly grazing management, locally available and affordable concentrate supplementations are recommended. Alternatively, use of tree fodder that can offer cheap protein supplements to the grazing animals should be considered.

Acknowledgements

The research was financed by the Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains (EPINAV) programme. The authors are grateful to the management of the Haydom Farm and Development Ltd. for providing experimental animals, grazing plot and animal housing.

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Table 1: Chemical composition and *in vitro* dry matter digestibility (in %) of key forage species and main feeds constituting concentrate mixture. (Mean values ± standard error.)

Species	DM	Ash	CP	NDF	ADF	INVDMD	INVOMD
Key forage species							
Bothriochloa insculpta	93.33 ± 0.49b	14.58 ± 0.05d	2.31 ± 0.02g	72.15 ± 0.37b	43.23 ± 0.22b	34.51 ± 0.26d	29.95 ± 0.55g
Cynodon dactylon	92.89 ± 0.49c	5.43 ± 0.05f	4.76 ± 0.02f	73.67 ± 0.37a	49.58 ± 0.22a	28.37 ± 0.26f	31.23 ± 0.55f
Cyperus rotundus	90.36 ± 0.49d	17.78 ± 0.05c	8.52 ± 0.02e	67.21 ± 0.37c	39.34 ± 0.22c	42.85 ± 0.26c	41.59 ± 0.55d
Indigofera indica	90.41 ± 0.49d	21.62 ± 0.05a	12.08 ± 0.02c	49.87 ± 0.37e	37.61 ± 0.22d	60.36 ± 0.26a	56.20 ± 0.55c
Tribulus terestris	90.54 ± 0.49d	20.28 ± 0.05b	14.19 ± 0.02b	45.19 ± 0.37f	33.19 ± 0.22e	33.39 ± 0.26e	37.71 ± 0.55e
Concentrate ingredients							
Maize Bran	92.52 ± 0.49c	4.4 ± 0.05g	10.89 ± 0.02d	35.58 ± 0.37g	4.87 ± 0.22f	60.80 ± 0.26a	66.87 ± 0.55a
Sunflower seed cake	93.87 ± 0.49a	5.77 ± 0.05e	19.95 ± 0.02a	60.89 ± 0.37d	42.68 ± 0.22b	57.68 ± 0.26b	60.67 ± 0.55b

Means within the same column with different letters are significantly different ($P < 0.05$)

Table 2: Time (in %) spent for different behavioral activities by supplemented and non-supplemented steers grazed on the natural pasture.

	Feeding duration (FD)		Dietary treatment (DT)		Time of day (TOD)		Significance[1]			
	2012 (n = 8)	2013 (n = 12)	PS (n = 10)	NP (n = 10)	AM (n = 10)	PM (n = 10)	FD	DT	TOD	DT*TOD
Feeding	49.89 ± 5.68	49.21 ± 4.75	32.28 ± 4.13	66.79 ± 4.13	48.48 ± 4.13	50.59 ± 4.13	NS	***	NS	NS
walking	29.32 ± 2.55	26.52 ± 2.11	31.91 ± 1.99	23.93 ± 1.99	32.13 ± 1.99	23.71 ± 1.99	NS	**	***	*
Stand/Rumin	3.93 ± 2.63	8.62 ± 2.15	11.72 ± 2.15	0.83 ± 2.15	2.07 ± 2.15	10.49 ± 2.15	NS	***	**	**
lying/rumin	2.13 ± 3.58	7.48 ± 3.03	9.09 ± 2.69	0.52 ± 2.69	6.15 ± 2.69	3.45 ± 2.69	NS	***	NS	NS
Idling	12.22 ± 3.05	4.02 ± 2.90	11.40 ± 2.97	4.84 ± 2.97	6.58 ± 2.97	9.65 ± 2.97	***	**	NS	NS
Others	2.48 ± 0.92	3.95 ± 0.75	3.54 ± 0.72	2.89 ± 0.72	4.57 ± 0.72	1.86 ± 0.72	NS	NS	**	*

[1]Significance levels are represented by *** = $P < 0.001$, ** = $P < 0.01$, * = $P \leq 0.05$ and NS. non-significant

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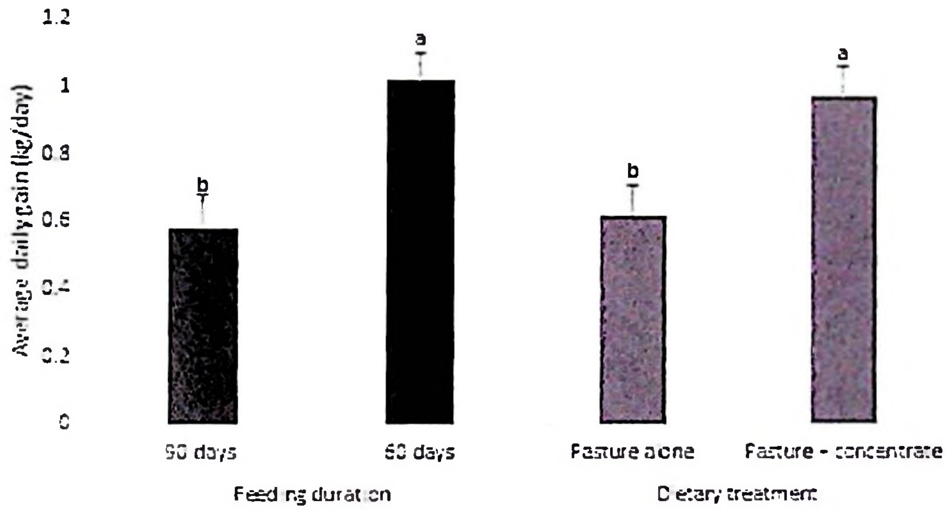


Figure 1: The mean weight gain (kg/day) for supplemented and non-supplemented steers recorded in two levels of finishing duration (90 days in 2012 Vs 60 days in 2013). Means with different letters are significantly different ($P \leq 0.05$).

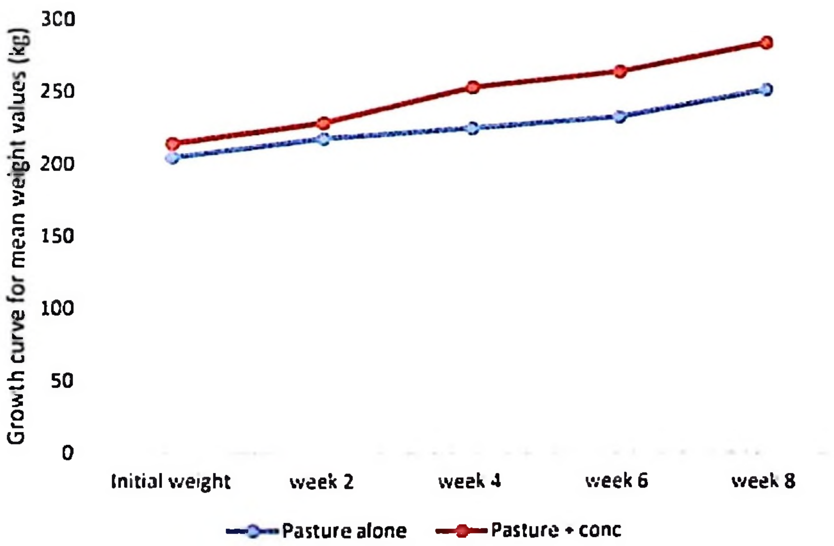
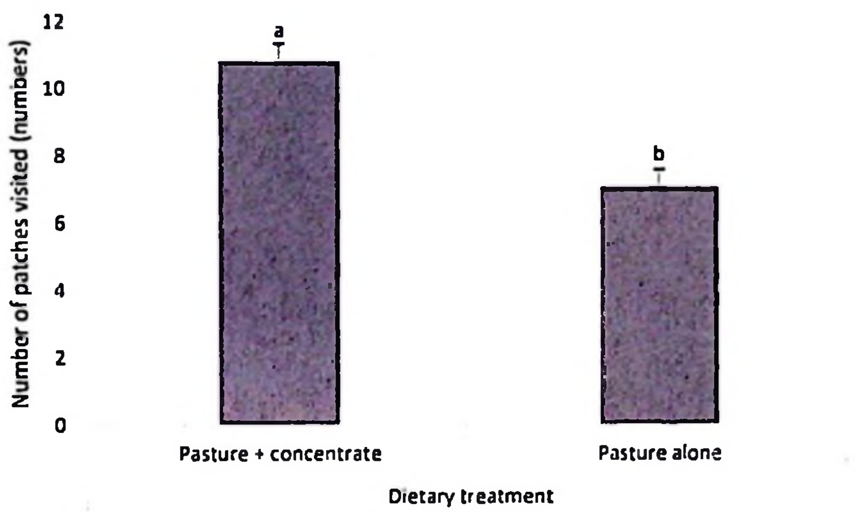


Figure 2: The progressive weight changes recorded every two weeks for both supplemented and non-supplemented Zebu steers

Figure 3: Interaction effect of dietary treatment and time of day on time spent in walking, standing + ruminating and other behavioural activities by Zebu steers grazed on natural pasture.

a



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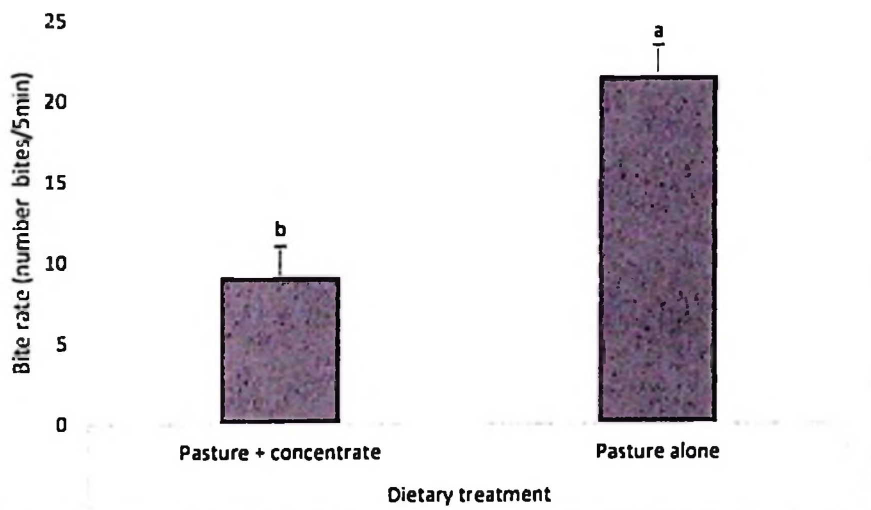

Figure 4: The mean (a) number of patches and (b) biterates for both supplemented and non-supplemented Zebu steers

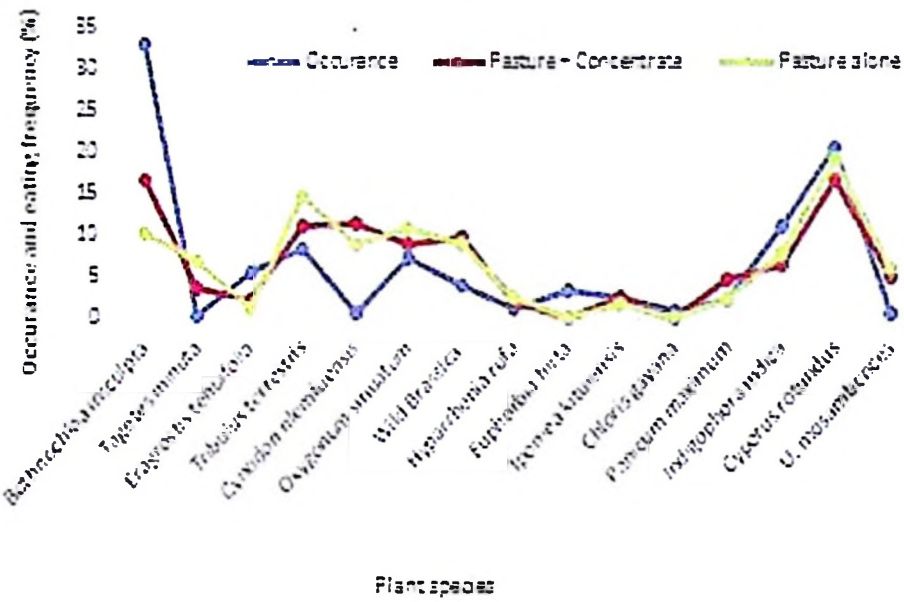

Figure 5: Averages for the abundance of individual species occurring in the grazing plot and the mean percentage eating frequencies per individual plant species recorded from focal animals for both supplemented and non-supplemented groups.

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PAPER 4

Feeding strategies for improved beef productivity and reduced GHG emission in Tanzania: Effect of type of finish-feeding on carcass yield and meat quality of Zebu Steers

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Abstract: The study was conducted to elucidate the effects of grazing on natural pastures alone versus total stall feeding on growth performance, carcass characteristics, and meat quality of Tanzania Zebu steers. In this experiment, 27 steers were distributed into 2 dietary groups; stall feeding (SF) and natural pasture feeding (NP). Animals in SF were totally confined in the feedlot with free access to wheat straw as a basal diet and supplemented with concentrate mixture, while those in NP were freely grazed on natural pasture. Animals in SF displayed 500 g higher average daily gain (ADG) and 4 units higher dressing percentage than those in NP. The marbling scores, hind leg length (HL), and hind leg circumference (Circ.) was also statistically higher among animals in SF than among those in NP ($P \leq 0.05$). Moreover, postmortem temperature was observed to decline more rapidly among animals in NP than in SF. However, postmortem carcass pH, meat tenderness, meat color, meat chemical composition (moisture content, dry matter (DM), ash, Either Extract (EE), and Crude Protein (CP) were independent of concentrate supplementation ($P > 0.05$). The high performance of the SF group in terms of ADG, dressing percentage, and intramuscular fat deposition was associated with utilization of high energy rich concentrate and improved utilization of wheat straw following concentrate supplementation. It

was concluded that, in addition to the manipulation of the animals' body through nutrition, other factors such as reducing pre-slaughter stress and appropriate ageing of meat should be manipulated to improve the meat quality of indigenous Zebu cattle.

Keywords: Concentrate, Pasture, Growth performance, Carcass, Meat quality

1.0 Background

Tanzania has a huge livestock resource base (NBS 2012). However, the productivity of this resource is lower than its potential mainly due to seasonality in the availability of feeds. Ruminant livestock production in the country depends largely on communal rangelands which are constrained by scarcity forage, particularly during the dry season. Animals undergo cycles of weight gain and loss in the wet and dry seasons, respectively (Kanuya et al. 2006); hence, it takes them a long time to reach the required live weights for slaughtering. Rubanza et al. (2003) confirmed that the available forages in the semi-arid rangelands of Tanzania are poor in quality and thus lead to severe weight losses in ruminants during the dry season.

The most promising approach to improve the quality of meat production from livestock ruminants and reducing greenhouse gas emission is through better nutrition. One of the basic principles is to increase digestibility of fibrous feedstuff through concentrate supplementation. McDonald et al. (2002) emphasized that to improve utilization of poor quality straws, provision of adequate supplies of high energy concentrates for the rumen microorganisms is crucial. High energy-rich concentrate provides sufficient fermentable nitrogen and carbohydrates, which enhance digestibility of poor quality roughage (Steinfeld et al. 2006).

The Hanang district in Manyara region comprises a larger proportion of semi-arid rangelands that are ideal for livestock production in the country (Mwilawa et al. 2008). The district is mainly occupied by the *Barabaig* semi-nomadic pastoralists with large herds of Zebu cattle. Previously, the *Barabaig* pastoral system was dependent on free movement of herders to utilize the most productive pastures (Lane 1994). Currently, these pastoralists are experiencing limited mobility due to diminishing grazing areas as a result of land alienation for the wheat production scheme. Since 1968, over 40,000 acres of productive grazing land has been declared by the government to the National Agriculture and Food Cooperation (NAFCO) for the wheat production scheme

(Lane 1994). These farms yield a substantial amount of wheat straw—approximately 132,000 tonnes per annum (Viggo 2008)—which can be used as potential sources of forage in the dry season. It can be argued that to sustain the livelihood of pastoral communities in the face of diminishing grazing resources, improved utilization of available crop residues is inevitable. Since wheat straws are low in nitrogen and high in lignocelluloses and hence have low digestibility and low voluntary intake (Forbes 2000), it is imperative to improve its utilization. In the last 10 years, these straws were considered to be too poor in nutritional value to be recommended for farm animals (McDonald et al. 2002). Although chemical treatment of straws may help to improve their utilization by increasing digestibility (Abebea et al. 2004), little effort has been made in Tanzania to increase the nutritional values of wheat straws through chemical treatment, partially due to the high cost of chemicals such as sodium hydroxide and ammonia. Moreover, the perceived risk of these chemicals as potential hazards to the environments limit their applications (Chaudhry 2000).

Despite the important role of crop residues as basal feed for ruminants, feeding animals with wheat straws alone is not adequate and cannot sustain high meat quality. Apart from chemical treatment, the nutritive value of crop residues can be improved by supplementation with other feedstuffs (Safari et al. 2011). According to Khandaker et al. (1998), wheat straw utilization could be improved by supplementation with high-energy feeds to provide sufficient fermentable nitrogen and carbohydrates. Nonetheless, the high cost of commercial concentrates coupled with poverty among Tanzanian pastoralists limit the use of concentrate feeds for meat production in the country. Moreover, there is paucity of information on how to improve production and quality of meat from Tanzanian Zebu steers found in semi-arid areas using locally available and cheap supplementary feeds. It is hypothesized that the absolute confinement of Zebu steers in the dry season with free access to wheat straw as basal diet and supplemented with locally made concentrate diet will improve growth performance and provide better meat quality than grazing them on natural pastures alone. Therefore, the current study seeks to elucidate the effects of dry season grazing alone vs. total confinement with free access to wheat straws and concentrate supplementation on growth performance, carcass characteristics, and meat quality of Tanzania Zebu steers.

2.0 Material and methods

2.1 Study area

The feeding trial was conducted in Haydom Farm and Development Ltd. in the Hanang district at Manyara region from November 2012 to February 2013. The climate in the study area is semi-arid characterized by two dry seasons—a long dry season, mainly from May to early November and a short dry season from December to February. The minimum and maximum temperatures range from 20°C to 30°C and the mean annual rainfall varies from 408 mm to 802 mm (Safari et al. 2011). The vegetation type is mainly wooded grassland dominated by acacia species, such as red acacia *(Vachellia seyal)*, umbrella thorn acacia *(Vachellia tortilis)*, and fever trees (*Vachellia xanthopholea)* with a herbaceous layer covered mainly by Africa star grass (*Cynodon nlemfuensis)*, creeping bluegrass (*Bothriocloa insculpta)*, nut grass *(Cyperus rotundus)*, devil's thorn *(Tribulus terrestris)*, thatching grass (*Hyparrhenia rufa)*, and buffel grass (*Cenchrus ciliaris)*. The area is mainly inhabited by the *Barabaig* pastoralists and cattle is the main livestock species (Lane 1994). The East Africa Short Horn Zebu cattle (*Bos inducus*) is the main breed in this area (Sieff 1997).

2.2 Feeding and animal management

A feeding trial was conducted for 90 days with a preliminary period of 14 days. Twenty seven Zebu steers aged between three and four years were selected from livestock keepers around Haydom wheat farm for the feeding trial. The selection of animals was based on pastoralists' willingness to participate in the project to add market value to their animals. Hence, prior to the feeding trial, a village meeting was held in which the objectives of the project and importance of the feeding trial were discussed with livestock keepers. Five pastoralists were engaged in the project and some of their animals were used in the feeding trial.

All selected animals were treated with synthetic pyrethroids prior to beginning the trial to control tick-borne diseases and other external parasites. Animals were distributed into two dietary treatment groups: total stall feeding (SF) and natural pastures alone (NP) with average initial weights (kg) of 250 ± 11 and 210 ± 13, respectively. Eleven animals were allowed to graze freely on NP during the day and 16 animals were totally confined with free access to wheat straw as a basal diet and supplemented with concentrate mixture (SF).

Stall feeding animals (SF), also referred to as feedlot animals, were offered a concentrate diet formulated from maize brain (70%), sunflower seed cake (27%), mineral mix (2%), and salts (1%), which are locally available and may be affordable to livestock keepers. Feedlot animals were group-fed with approximately 75 kg DM of concentrates per day. They were given concentrates in two lots, at 8:00 hrs and at 15:00 hrs. All feedlot animals were given wheat straw *ad libitum* and had free access to water. Both concentrates and wheat straw were weighed every day before feeding and residues were collected daily in the morning and weighed for estimation of feed intake.

The NP group was not given concentrate and grazed solely on natural pasture. The studied animals in this group were herded together and the group was released on pasture from 9:00 am to 5:00 pm every day. They were grazed on a grazing plot of 111.6 ha within the Haydom farm. The selected grazing plot was familiar to the studied animals and the vegetation composition was mainly herbaceous plants with scattered acacia woody species. The live weights of animals in both groups were recorded at the beginning of the feeding trial and after every two weeks until the experiment ended. The weight gain (kg/day) of each animal was calculated by subtracting the initial body weight from final body weight and divided by the number of days when animals were undergoing the feeding trial.

2.3 Slaughtering procedures

Following the completion of the feeding trial, all 27 animals were transported to the Arusha Meat Company in Arusha town, approximately 280 km away, for slaughtering and chilling. All animals were fasted for approximately 12 hrs before slaughtering. They were rested in the waiting area (lairage) for approximately 12 hrs to recover from transportation stress. Final live weights were recorded before slaughtering, one day prior to slaughtering. The slaughtering and dressing followed the abattoir procedure, as given by Bourguet et al. (2011). Hot carcass weights were recorded immediately after slaughtering and the carcasses were split into two halves through the median plane. Dressed carcasses were obtained after removing skin, viscera, head from the occipito-atlantal joint, fore feet at the carpal-metacarpal joint, and hind feet at the tarsalmetatarsal joint, as described by Mapiye et al. (2009). Thereafter, four hrs post-slaughtering, dressed carcasses were taken into the chilling room (10°C) for 20 hrs. The *Longissimus dorsi* (LD) samples were excised from the carcasses 24 hours postmortem, vacuum packed, frozen, and transported chilled on ice to the Department of Animal Science and Production, Sokoine University of Agriculture (SUA) for physico-chemical analyses. The dressing out percentage was estimated as the ratio of hot carcass weight to slaughter live weight multiplied by 100.

2.4 Post slaughter measurements

The temperature and pH of the remaining half carcasses were recorded at 45 minutes, 6, 12, and 24 hours postmortem. The pH was measured by using a portable pH-meter (Portamess, Knick, Berlin, Germany) with a gel electrode (InLab, Mettler-Toledo, Greifensee, Switzerland) inserted in the geometric center of the LD muscle. Various linear measurements of carcasses were taken, such as carcass length (CL, from the lumbo-sacral joint to the cervical-thoracic joint), carcass depth (CD, from the dorsal to ventral edge of the carcass side along the ninth rib), and hind leg length (HL) and circumference (HC).

2.5 Chemical composition of feeds and minced LD samples

The chemical composition of key forage species sampled from natural pastures and the feed ingredients constituting the concentrate mixture were analyzed following the procedures of the AOAC (2002) for moisture content, dry matter (DM), ash, crude protein (CP), and Ether Extract (EE). Neutral and acid detergent fiber (NDF and ADF) were analyzed according to the method given by Van Soest and Robertson (1991). *In vitro* dry matter digestibility (INVDMD) and organic matter digestibility (INVOMD) were determined using the two-stage technique of Tilley and Terry (1963).

The LD samples were thawed and chemical analyses were conducted in the Department of Animal Science and Production, Sokoine University of Agriculture (SUA). The samples were minced homogeneously before chemical analyses. The chemical composition of meat was determined according to AOAC (2002). Dried matter and water content were estimated after the samples were dried for 48 hrs at 100°C. Ash content was determined by subjecting dried samples at 550°C in a muffle furnace for 3 hrs. Crude protein was determined following the Kjeldahl method.

2.6 Determination of meat tenderness and cooking loss

Meat tenderness was determined by measuring the amount of force required to shear across muscle fibers following the procedure described by Boccard et al. (1981). The Warner-Bratzler Shear Force (WBSF) machine (Zwick/Roell Z2.5, Germany) installed in the Department of Animal Science and Production-SUA was used for this measurement. The LD steak samples from 27 animals were cooked at a core temperature of 70°C in a water bath held at 80°C. The internal temperature of the steaks was measured using a digital thermometer. The steaks were chilled at 4°C overnight and cut parallel to the muscle fibers into 1 × 1 cm cubes. Meat tenderness was measured as the maximum force (N/cm^2) required for shearing the cubes perpendicular to the muscles at a crosshead speed of 100 mm/min using the Warner-Bratzler shear force blade. The average peak shear forces of 12 cubes per muscle sample were taken as the force required to shear a particular animal's muscle.

The cooking loss was determined by measuring the weight change of meat samples after thawing, followed by vacuum packing and cooking in a water bath at 80°C for 1 hr. All samples were weighed before cooking (W1). Cooked samples were chilled in running water from the tape for approximately 2 min and transferred to the refrigerator set at 4°C overnight, blotted dry, and weighed again (W2). Cooking loss was computed as the proportion of the weight of raw thawed steaks lost as a result of cooking, that is, Cooking loss = Weight of raw steak after thawing (W1) – Weight of cooked steak (W2)/ Weight of raw steak after thawing (W1) × 100.

2.7 Color and marbling determination

The color at the rib eye of LD muscles was assessed on chilled samples (after thawing) and scored against standard color chart references (Nickerson 1946). A panel of three experienced assessors scored color using an eleven point scale: 1 = pale, 2 = light red, 3 = red, 4 = light dark red, 5 = very dark red, 6 = light brown, 7 = brown, 8 = very brown, 9 = slightly bleached, 10 = bleached, and 11 = highly bleached. The average scores from three assessors was considered the color of a particular muscle sample. Similarly, the amount of intra-muscular fat (marbling) was assessed using the standard marbling grading system (Shiranita et al. 2000). The marbling score chart used in this study has six point scales ranging from 1 = slight, 2 = small, 3 = modest, 4 = moderate, 5 = slightly abundant, and 6 = moderately abundant.

2.8 Statistical analysis

Data were analyzed using the General Linear Model procedure of SAS (2004) for effects of dietary feeding treatment on weight gain, carcass characteristics, and meat quality. The dietary treatments were considered independent factors whereas live-weight gain, carcass characteristics, and meat quality were considered dependent factors. The initial weights of experimental animals were entered into the model as covariate. The Least Square Means (lsmeans) differences were tested using t-test. Similarly, the results for the chemical analyses of feed samples were subjected to GLM of SAS (2004).

3.0 Results

The daily dry matter intake for concentrate and wheat straw for stall-fed animals was 4.6 kg and 2.8 kg/head, respectively. Figures 1a & 1b present the least-square means for daily weight gain and dressing percentage, respectively. It is evident that SF animals displayed 500 g higher ADG and 4 units higher dressing percentage than NP animals with respective P values of 0.01 and 0.03. Table 1 presents the results for chemical analysis of forage samples collected from the grazing plot (natural pastures) and feed samples constituting the concentrate mixture. Higher variations were observed in the chemical composition of feed samples. Most key forage species from natural pastures displayed low values for CP content, high NDF & ADF, and reduced digestibility (INVDMD & INVOMD) as compared to the feed ingredients constituting the concentrate mixture.

Table 2 presented the lsmeans for chemical analyses of meat samples (DM, ash CP and EE), carcass linear measurements (CL, CD, HL, and Circ.), and meat quality parameters (meat color, marbling, tenderness and cooking loss). The lsmeans for chemical analyses were found to have no significant difference between SF and NP. In terms of carcass linear measurement, HL and Circ. were significantly higher in SF than NP. However, the values for CL and CD were not significantly different between SF and NP.

Dietary treatments were found to have significant impact on accumulation of intramuscular fat (Table 2). Further, SF steers were found to have higher lsmeans for marbling scores than NP ($P = 0.01$). Nevertheless, dietary treatment was found to have no significant ($P > 0.05$) effect on meat color, tenderness, and cooking loss.

Figure 2 presents the lsmeans values for pH and temperature measured at 45 minutes, 6 hrs, 12 hrs, and 24 hrs. The initial carcass temperature for NP was higher than SF but declined rapidly at 6 hrs, 12 hrs, and 24 hrs. Therefore, the lsmeans values of temperature for NP at 6 hrs, 12 hrs, and 24 hrs were significantly lower than SF. The pH values between SF and NP were not significantly different.

4.0 Discussion

The observed variation in weight gain between SF and NP is most likely a reflection of the impact of dietary treatments on growth performance. The reduced daily weight gain observed in the NP group might be associated with a decline in the quality of natural pasture in the dry season (Rubanza et al. 2003). Most of the key forage species collected from natural pasture were found to have low CP level, high cell wall contents (NDF & ADF), and reduced *in vitro* digestibility (INVDMD & INVOMD). Apart from chemical composition and digestibility of the pastures, the physical nature of the pasture probably contributed negatively to the feed intake for NP. McDonald et al. (2002) indicated that the physical structure and distribution of pasture are the main factors determining feed intake in grazing ruminants. Animals grazing in heterogeneous pastures spent substantial amount of time and energy in organizing the grazing process compared to feedlot animals. Therefore, reduced weight gain in animals grazed on natural pastures can also be explained by energy expenditure for muscular efforts such as walking. According to Lachica and Aguilera (2005), energy expenditure of grazing animals exceed those of confined animals.

On the other hand, the increased daily weight gain in SF may be due to the supplement of high quality concentrate. The chemical composition of the ingredients constituting the concentrate mixture had relatively higher CP values and low NDF than the forage species from NP. Moreover, the digestibility of the concentrate mixture was relatively higher because of high concentration of rapid fermentable cell contents and low cell wall contents (NDF and ADF). Moreover, improved weight gain in this group was probably due to the improved utilization of poor quality wheat straw following supplementation with concentrates. According to Khandaker et al. (1998), supplementing animals' diet with concentrate improves voluntary intake and digestibility of wheat straw. The degradation of feed in the rumen by microbes requires high concentration of N that increases digestibility and consequently voluntary intake of roughage (Rokomatu & Aregheore 2006). Morita et al. (1996) reported that the inclusion of concentrates in animals' feeds aids digestion of fiber in the rumen.

The relatively high values for dressing percentage observed in the feedlot animals compared to pasture grazed animals are in agreement with the findings of Moron-Fuenmayor and Clavero (1999). These variations might be associated with great fat deposition in the muscles of concentrate-fed animals. Cattle with higher fat deposition in the muscles usually produced higher dressing percentage (Van Koevering et al. 1995). However, in this study, the values for dressing percentages of supplemented Zebu steers were relatively lower (42%) than those of Nguni steers (53%) (Mapiye et al. 2009), Angus steers (53.7%), Bonsmara steers (56.9%) (Muchenje et al. 2008), and crossbred steers (64–66%) (Montgomery et al. 2009). These differences are most likely due to variation in breed types and the rearing husbandry systems, because the animals finished under this feeding trial were local breed grown on poor pastures.

Further, variation in carcass linear measurements implies a high growth rate in animals supplemented with concentrate diet than pasture grazed animals. These variations may have significant implication on meat quality traits, particularly meat tenderness. Rapidly growing animals tend to have tender meat due to increased protein turnover (French et al. 2001). However, the observed non-significant difference in meat tenderness between SF and NP was not correlated with their growth performance. These findings are in line with the report by Lowe et al. (2002) and Moloney et al. (2001) who found a poor correlation between pre-slaughter growth rate and meat tenderness. Therefore, meat tenderness may be influenced by other factors than growth performance. Gomes et al. (2012) found a positive correlation between meat tenderness of steers and their phenotypic traits rather than weight gain. According to Muchenje et al. (2009a), indigenous breeds—such as Nguni and Zebu—are considered to have tougher meat than exotic breeds. According to the authors, indigenous breeds have a high *calpastatin* activity that inhibits *calpains* activity, thereby leading to slower degradation of muscle postmortem. According to Gomes (2012), the negative effect of tenderization in *B. indicus* is primarily associated with *calpain* system activity. Moreover, pre-slaughtering handling stresses can have a significant influence on the tenderization of meat. Devine et al. (2006) considered pre-slaughter stress due to transportation and handling as a major factor affecting meat tenderness. Stressed animals tend to release a high amount of catecholamines (Muchenje et al. 2009b) that influences depletion of glycogen and subsequently affects postmortem tenderization. In the present study, animals travelled 280 km for 20 hrs before slaughter. Therefore, to improve meat quality, several factors other than the manipulation of body weight should be considered, such as reducing pre-slaughter stress and adequate ageing of meat.

In line with increased carcass weight following concentrate supplementation, there was a significant increase in intra-muscular fat, as reflected by high lsmeans values for marbling scores in SF than NP. This concurred with Bruns et al.'s (2004) study, who found a positive correlation between increased carcass weight and intramuscular fat in finishing steers. Vestergaard et al. (2000) also found a markedly reduced intramuscular fat of the bulls raised on pasture than those finished on concentrate supplements. Increase in intramuscular fat is associated with increased tenderization of meat (Mushi et al. 2007). Muir et al. (1998) associated carcasses with high level of intramuscular fat with slow cooling that prolongs the postmortem proteolysis process which in turn increases meat tenderness. In the present study, a similar relationship was observed whereby concentrate-fed SF steers displayed slower postmortem temperature decline than NP. In addition to meat tenderness, marbling has also been associated with increased juiciness, flavor, and overall acceptability of meat by consumers (Muchenje et al. 2009a).

Meat color is an important factor affecting meat acceptability among consumers. Despite the variation in intramuscular fat between SF and NP animals, concentrate supplementation was found to have little effect on meat color. Although the higher amount of intramuscular fat was expected to increase the brightness of meat, there was only a weak relationship between marbling scores and meat color scores in this study. Lack of variation in meat color between pasture-fed and concentrate-fed animals contradict the findings reported by Baublits et al. (2004), which indicated the tendency of grass fed-animals to have darker meat than concentrate-fed animals. French et al. (2001) and Priolo et al. (2001) also found no significant difference in meat color between grass-fed animals and concentrate-fed ones.

5.0 Conclusion

The overall performance of feedlot animals was relatively better in terms of ADG, dressing percentage, and intramuscular fat deposition compared to pasture-fed animals. This has been associated with utilization of high energy-rich concentrates and improved utilization of wheat straw in feedlot animals following supplementation. On the contrary, the poor performance of pasture-fed animals is related to poor quality of forages, physical structure, distribution of forage resources, and energy expenditure for locomotion on the natural pasture. However, the concentrate feeding system in the present study had limited effects on meat tenderness. Therefore, other factors like pre-slaughter stress and postmortem carcass handling are likely to have overriding effects on meat tenderness compared to feeding.

Acknowledgments

This research was financed by the Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains (EPINAV) program. Further, the authors are grateful to the management of the Haydom Farm and Development Ltd for their help in cattle handling within their farm.

Table 1: Chemical composition of key forage species and feed ingredients constituting concentrate mixture

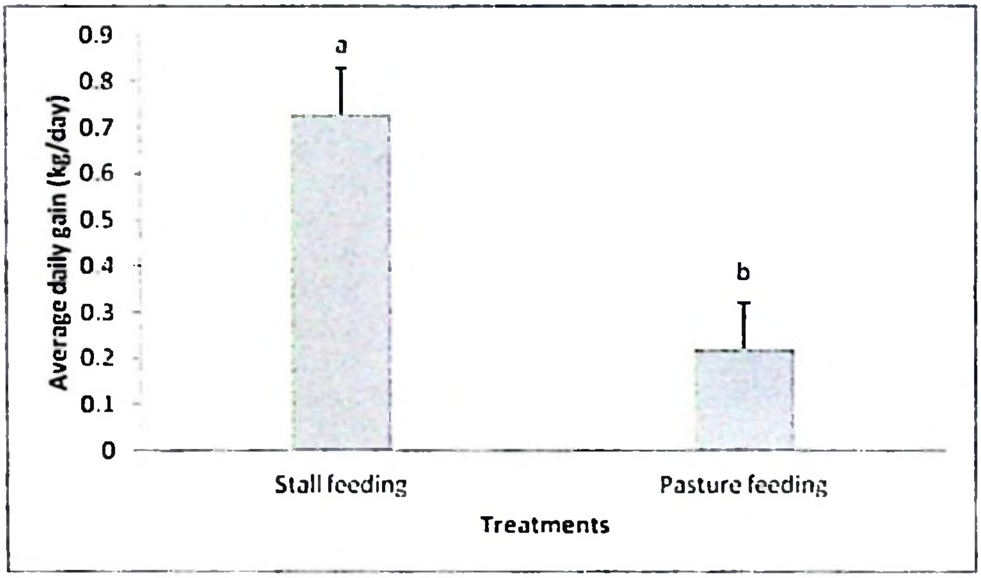
Sample	DM	Ash	CP	NDF	ADF	INVDMD	INVOMD
Key forage species							
Bothriochloa isculpta	93.33b	14.59d	2.32h	72.16c	43.23d	34.41f	29.86h
Cenchrus ciliaris	92.59c	6.25g	6.37f	67.21d	46.26c	51.74c	53.47d
Cynodon dactylon	92.89c	5.44h	4.77g	73.67b	49.58b	28.37i	31.24g
Cyperus rutondus	90.37d	17.79c	8.53e	67.21d	39.34e	42.85e	41.60f
Hyparrhenia rufa	93.36b	7.62f	1.90i	86.24a	53.86a	31.94h	34.08
Indigofera indica	90.41d	21.62a	12.08c	49.87f	37.61f	60.36a	56.21c
Tribulus terrestris	90.55d	20.29b	14.20b	45.19	33.19g	33.39g	31.71g
Wheat straw	93.38b	11.45e	5.64	67.87d	37.61f	50.47d	50.09e
Concentrate mixture							
Maize bran	92.53c	4.40h	10.89d	35.58g	4.88h	60.81a	66.87a
Sunflower seed cake	93.84a	5.77g	19.96a	60.89e	42.69d	57.68b	60.98b
SE	1.36	6.59	5.68	15.06	13.41	12.56	13.66

*Composition of mineral pre-mix: 29.94 % Calcium, 0.4% Sodium, 11.0% Phosphorus, 27.0% Chloride, 27.0% Nitrate, 3.0% Magnesium, 0.5% Iron, 0.5% Manganese, 0.5% Zinc, and 0.16% Copper.

Table 2: Chemical composition, carcass linear measurements, and meat quality parameters of steers fed with different diet compositions.

Variables	Treatments		
	Stall feeding (SF)	Natural pasture (NP)	Significance
Chemical analysis (%)			
Moisture content	73.62 ± 0.92	74.21 ± 1.14	0.70
Dry matter (DM)	26.37 ± 0.92	25.78 ± 1.14	0.70
Ash	17.86 ± 1.14	18.41 ± 1.41	0.77
Crude protein (CP)	22.43 ± 0.60	22.28 ± 0.73	0.87
Ether extract (EE)	1.64 ± 0.51	0.59 ± 0.42	0.13
Carcass linear measurement (cm)			
Carcass length (CL)	86.71 ± 1.09	84.60 ± 1.33	0.25
Chest depth (CD)	55.03 ± 2.06	53.80 ± 2.53	0.72
Hind leg length (HL)	88.18 ± 0.67	85.19 ± 0.82	0.01
Hind leg circumference (Circ.)	84.63 ± 0.97	79.63 ± 1.20	0.01
Meat quality parameters			
Color scores[1]	3.96 ± 0.47	3.24 ± 0.57	0.36
Marbling scores[2]	2.93 ± 0.17	2.10 ± 0.21	0.01
Tenderness (shear force N/cm2)	57.62 ± 4.54	60.49 ± 5.57	0.71
Cooking loss (%)	20.06 ± 1.68	21.14 ± 2.06	0.70

a



b

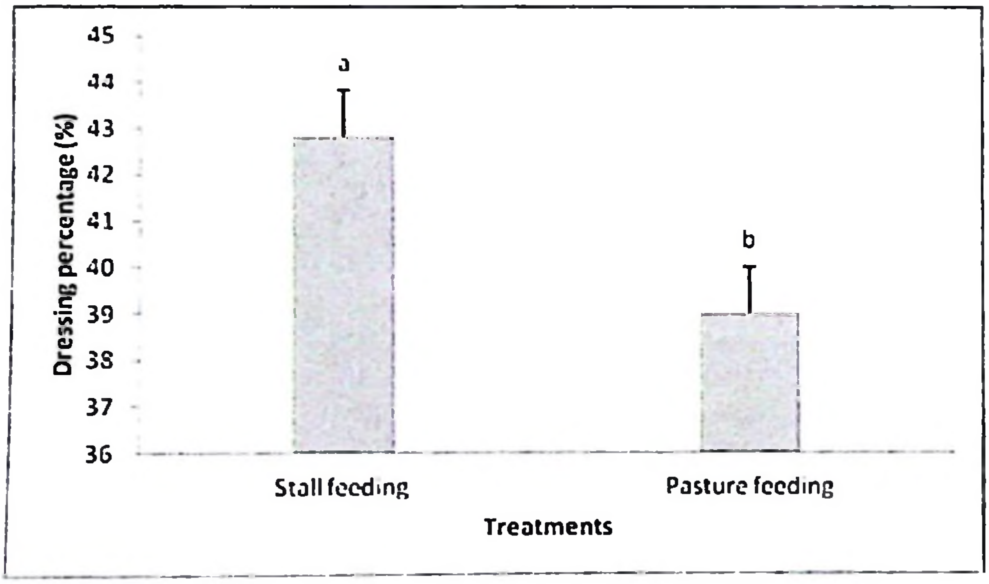
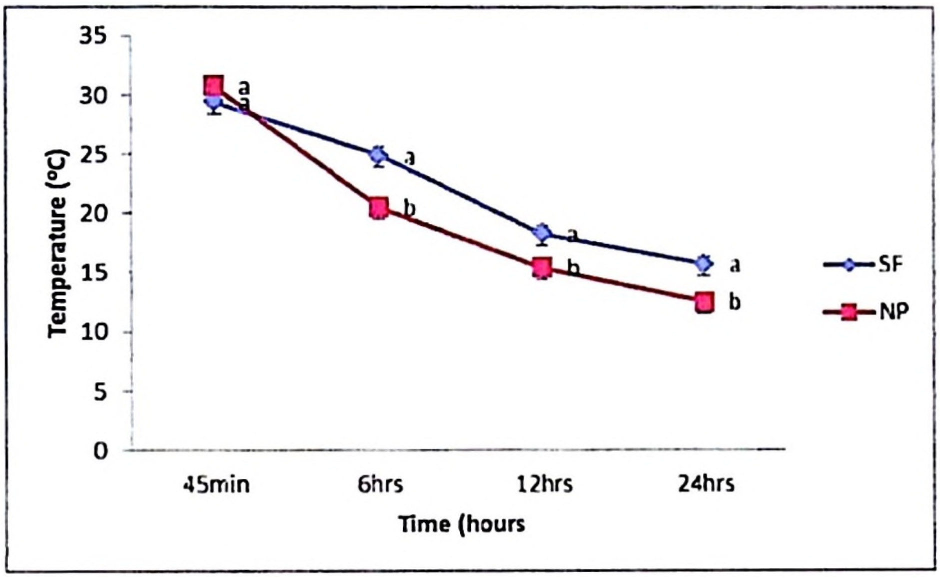


Figure 1: Daily weight gain (a) and dressing percentage (b) of steers under stall feeding and the pasture feeding trial

a



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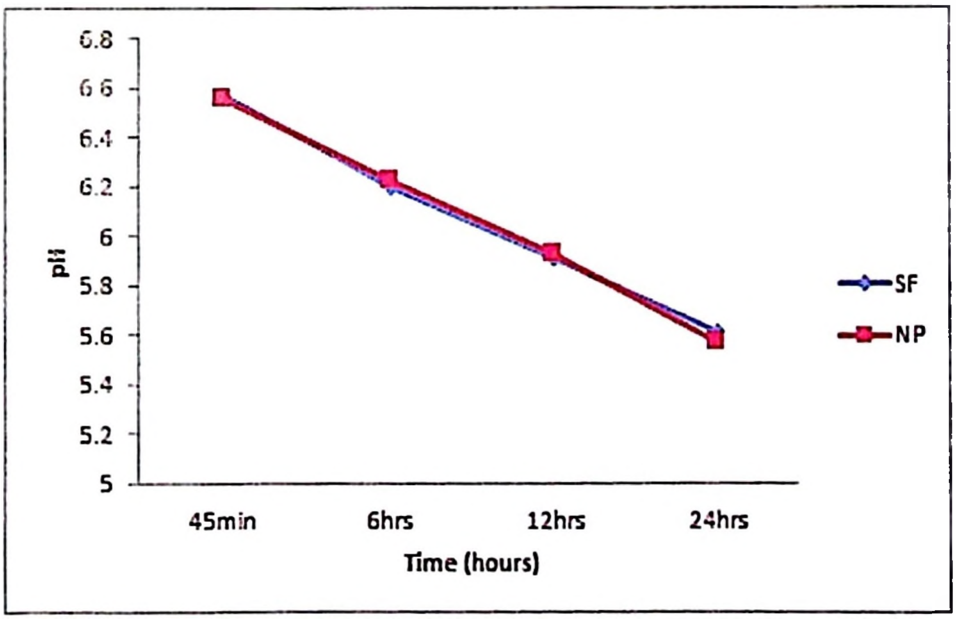

Figure 2: The post mortem temperature (°C) and pH measured for carcasses from animals fed different diet

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