Universität für Bodenkultur Wien (University for Applied Life Sciences Vienna)

Department für nachhaltige Agrarsysteme (Department of Sustainable Agricultural Systems)

Institut für Nutztierwissenschaften (Division of Livestock Sciences)

Leiter (Head): Univ. Prof. Dr. Christoph Winckler

Analysis of pastures and pasture management on dairy cattle farms in south-western Uganda

(Untersuchungen von Weideflächen und Weidemanagement auf ausgewählten Milchrinderbetrieben im südwestlichen Uganda)

Diplomarbeit ausgeführt zum Zweck der Erlangung des akademischen Grades einer Diplom Ingenieurin

vorgelegt von (submitted by) Romana Katharina Roschinsky

Beurteiler (examiner): Univ. Prof. Dr. Johann Sölkner

Betreuer (supervisors): Dr. Maria Wurzinger
Msc. Henry Mulindwa

Wien, Mai 2009

Danksagung (Acknowledgments)

Zu allererst möchte ich meinen Eltern danken, die mein Studium ermöglicht und mich auf jede erdenkliche Weise immer unterstützt haben. Der Weg durch das Studium war nicht immer leicht und ich konnte immer auf sie zählen. Auch dem Rest meiner Familie möchte ich danken!

Mein Dank gilt meinen Betreuern: Univ. Prof. Dr. Johann Sölkner und Dr. Maria Wurzinger. Die wunderbare Zusammenarbeit und die große Unterstützung im Laufe dieser Diplomarbeit haben einen erfolgreichen Abschluss erst ermöglicht. Ich bin sehr dankbar, dass ich die Chance bekommen habe, die Feldarbeit in Uganda durchzuführen und so die Möglichkeit hatte, eine für mich vollkommen neue Kultur kennenzulernen. Die Betreuung war erstklassig und ich habe sie immer sehr zu schätzen gewusst.

I want to thank Msc. Henry Mulindwa and Msc Esau Galukande for their support in course of this study. From day one they have integrated me into the team and without them field work would not have been possible. Hours and hours of cutting and measuring plants would have been impossible to complete without Henry. And without Esau´s support, I would never have found out about room number 4 at Pelican Hotel and it´s "special qualities". Apart from general support…their tire changing accomplishments are divine.

Dr. Asiimwe has been greatly supporting field work in Mbarara. Many thanks to Dr. Okeyo from ILRI and Dr. Semambo from NAGRC&DB for their support. I also want to thank NARO for supplying a vehicle for three weeks of field work.

Dr. Denis Mpairwe has been greatly supportive at Makerere University and very helpful during my stay in Kampala in general. Mr. Katongole helped me to familiarize with laboratory analysis at Makerere and has been very patient in explaining analyses to me. Many thanks also the rest of laboratory staff.

Ich möchte der BOKU danken, die durch die Gewährung des „Stipendiums für kurzfristige wissenschaftliche Arbeiten“ die Durchführung dieser Diplomarbeit unterstützt hat. Ebenso dem „Siegfried Ludwig Fonds“ des Landes Niederösterreich für die Gewährung eines Stipendiums.

Natürlich danke ich auch meinen FreundInnen (☺) und StudienkollegInnen, ohne deren Hilfe und „Mitwirkung“ ich sicherlich keine so schöne Zeit an der BOKU verbracht hätte. Das familiäre Klima hat mein Studium zu etwas Besonderem gemacht. Ohne Bibliotheksrunde und Tüwibesuche hätte ein wichtiger Teil gefehlt! Ich hoffe alle finden in Zukunft, auch Abseits des Studiums, eine so schöne Gemeinschaft.

Last but not least I want to dedicate this thesis to my friend Robert Bain who has always been a great supporter of mine, readily giving advice and has sadly passed shortly after my return from Uganda.

Table of contents

Abstract

Pastoralists of south-west Uganda crossbreed Holstein Friesian bulls with indigenous Ankole cattle. Aim of this breeding strategy is to enhance milk yields. Present diploma thesis wants to find out, if there are differences between pastures stocked with different breeds. Data on pasture management, pasture vegetation, plant traits, pasture productivity and nutrient composition was collected on 10 farms close to Mbarara.

Analysis of collected data lead to following results: There are differences in pasture management and in effects of bushes, shrubs and trees between pastures stocked with different breeds. Pastures stocked with Ankole cattle were more likely to be subjected to erosion. Composition of herbaceous pasture vegetation is changing. Problems caused by weeds are independent from herd type a pasture is stocked with. There are significant differences in some plant traits between pastures stocked with different breeds. Fresh and dry matter yields are significantly different but dry matter content did not show significant differences between pastures stocked with different breeds. Of all nutrients analyzed only crude protein content showed significant differences between pastures stocked with different breeds.

Various reasons for the occurring differences are discussed. But the most important reason may be the preselection of better pastures for crossbred cattle acknowledged by farmers.

Zusammenfassung

Viehhalter im südwestlichen Uganda kreuzen Holstein Friesen Bullen mit autochtonen Ankole Rindern. Ziel dieser Praxis ist die Steigerung des Milchertrages. Vorliegende Diplomarbeit möchte herausfinden, ob es Unterschiede gibt zwischen Weiden, die mit unterschiedlichen Rassen bestoßen werden. Daten über Weidemanagement, Weidevegetation, Pflanzeneigenschaften, Weideertrag und Nährstoffzusammensetzung wurden auf 10 Betrieben in der Nähe von Mbarara gesammelt.

Die Analyse der gesammelten Daten kam zu folgenden Ergebnissen: Es gibt Unterschiede Im Weidemanagement und in den Auswirkungen von Büschen, Sträuchern und Bäumen zwischen Weiden bestoßen mit unterschiedlichen Herden. Ankole Weiden waren eher Erosion unterworfen als Weiden von Kreuzungstieren. Die Zusammensetzung der krautigen Weidevegetation ändert sich. Probleme durch Unkräuter sind unabhängig vom Herdentyp. Einige Pflanzeneigenschaften und der Rohproteingehalt der Weideproben weisen signifikante Unterschiede zwischen verschiedenen Herdentypen auf. Frisch- und Trockenmasse, nicht jedoch Trockemassegehalt weisen signifikante Unterschiede zwischen den Herdentypen auf.

Für vorkommende Unterschiede ist, von den unterschiedlichen, diskutierten Gründen, die von Bauern eingestandene, von vornherein stattfindende Zuteilung besserer Flächen für die Beweidung durch Kreuzungstiere der wahrscheinlichste Grund.

1. Introduction

This diploma thesis is part of a research project titled: “Evaluation of ecological and economic sustainability of breeding strategies in pastoral systems: The case of Ankole cattle in Uganda” which is conducted by the University of Applied Life Sciences (Universität für Bodenkultur - BOKU), Vienna in partnership with the International Livestock Research Institute (ILRI), Nairobi, Kenya, the Makerere University, Kampala, Uganda and the National Animal Genetic Resource Centre and Data Bank (NAGRC&DB), Entebbe, Uganda.This thesis has been supervised by Univ. Prof. Dr. Johann Sölkner, Dr. Maria Wurzinger and supported by two PhD candidates involved in the project: Msc. Esau Galukande and Msc. Henry Mulindwa. At Makerere University work was supported by Dr. Denis Mpairwe and laboratory work by Mr. Iganatius Katongole. On farm data collection was supported by Dr. Grace Asiimwe, veterinarian and local project partner in Mbarara area. He conducted most interviews during first round of data collection. The National Agricultural Research Institute of Uganda (NARO) supplied a vehicle for three weeks of field work.

Pastoralists in the South-West of Uganda have developed a breeding strategy of splitting their herds of indigenous Ankole cattle in 2, keeping 1 herd pure-bred indigenous Ankole cattle (Fig. 1) and mating the other herd with Holstein Friesian bulls (Fig. 2). The project investigates sustainability of keeping crossbred cattle in harsh environmental conditions and whether this strategy leads to soil erosion due to overgrazing. As project contribution, data on pasture flora, pasture yield, pasture quality and pasture management in the study area was collected in course of this thesis.

Fig. 1 Ankole cattle

Fig. 2 Ankole x Holstein Friesian cattle

It was an objective of this work to find out if the herd type which grazes on a paddock influences pastures. This means not only an influence of breed itself, but also of accompanying management decisions made by farmers.

To gain information on herbaceous and non herbaceous plants and their qualities from farmers was an additional aim of this thesis. Although the study concentrated on data collected from certain pastures, especially information about changes in vegetation and species composition proved useful for interpretation of trial results.

Farmers involved were research partners, as information they gave, about pasture management, problems with erosion and vegetation, was vital in answering research questions. Farmers´ expertise has been needed to identify appropriate sites for data collection. Their knowledge of native flora, has been valuable, additional information for assessment of pasture yield, pasture quality and improvement methods.

It was decided beforehand to combine survey of pasture management with field data from selected pastures on 10 farms participating in the project. On each chosen farm 1 pasture stocked with Ankole x Holstein Friesian cattle and 1 pasture stocked with purebred Ankole cattle was chosen for sample collection. Sample collection concentrated on single plant traits influenced by grazing and productivity samples collected on representative sites of each pasture. Furthermore pasture samples were later analysed for key nutrient contents and energy content. Analysis of data initially aimed at comparing between pastures stocked with different breeds. Where applicable a comparison between different farms and between samples collected during different seasons was also done.

The field work gave an interesting insight into pasture management practiced on the study farms and the overall project will hopefully benefit from this thesis´ contribution.

1.1. Objectives

The first objective of this work is to determine, if there are differences between pastures stocked with Ankole and pastures stocked with Ankole x Holstein Friesian cattle. It aims at comparing different parameters within and between farms, between breeds and between seasons. Selected plant traits, selected nutrients, pasture productivity, pasture vegetation and pasture management were assessed. By using statistical tools probable differences within and between farms, between pastures stocked with different breeds and between seasons are to be ascertained. This will be used to determine, if introduction of crossbred Ankole x Holstein Friesian cattle has an impact on pastures of 10 dairy farms in the study area and if these differences can be connected to herd type grazing respective paddocks.

A second objective is to collect data on qualities of area-typical pasture plants. To establish how farmers estimate plants qualities and abundance. To determine changes in pasture composition over the past ten years. Thereby not only focusing on herbaceous pasture plants, but also on bush, shrub and tree growth.

1.2. Hypotheses

Following hypotheses have been central for this study.

There is no difference in pasture management between pastures stocked with different breeds.

There is no difference in the impact of erosion between pastures stocked with different breeds.

There is no difference in bush, shrub and tree abundance between pastures stocked with different breeds.

There are no differences in selected plant functional traits between individual farms and pastures stocked with different breeds.

There are no difference in pasture productivity between individual farms, between pastures stocked with different breeds and between seasons.

There are no differences in selected nutrients of pasture samples between individual farms, between pastures stocked with different breeds and between seasons.

2. Literature Review

2.1. Literature research

Main sources for literature research previous to field work have been online databases provided by the library of the University of Applied Life Sciences (Universität für Bodenkultur - BOKU), Vienna.

Online databases used were:

- SCOPUS database
- Science Direct online

In addition hard copies of journals were used. Literature research started around middle of January 2008. During field work there was the opportunity to use resources of Makerere University Kampala, Uganda. These included hardcopies of literature on agriculture and vegetation in Uganda and also the use of AGORA database for further online research.

2.2. Introduction to Uganda and its agricultural sector

Uganda lies astride the equator, between latitudes 4° 12´ N and 1° 29´ S and longitudes 29° 34´ E, and 35° 0´ E. It is a landlocked country in East Africa. Uganda´s neighbours are Sudan to the north, Kenya to the east, Tanzania and Rwanda to the south and the Democratic Republic of Congo the west (Jameson, 1970).

Uganda has a total land area of 241 548 km² (Table 1). More than 75% of the country (over 18 million hectares) or cultivated and pasture. Pastures and grazing land are estimated to ad up to over 16 million hectares, half of which (8.4 million hectares) are extensive grazing land. Improved pastures are estimated to comprise only 1.8 million hectares (Mwebaze, 2008).

Table 1. Current agricultural land use and potential grazing areas of Uganda (Statistical Abstracts, MFP&ED, June 1997 in Mwebaze, 2008)

land classification	square kilometres	percentage
grassland	51 118.6	21.16
farmland	83 931.0	34.75
woodland	40 277.7	16.67
bush	14 198.6	5.88
total potential grazing land	189 525.9	78.46
total land area	241 548.0	100

Agriculture is the backbone of Uganda's economy. 95% of the population farms (both crops and livestock). On small farms for food and cash income, and also on fairly large farms, including ranches of an average size of 1 200 ha, and crop farms of 5 - 20 ha. Agriculture contributes over 40% to the Gross Domestic Product (GDP) and over 90% to the country's foreign exchange earnings. It also contributes over 60% of total Government revenue in addition to employing more than 80% of total labour force and providing over half of total income for the bottom three-quarters of the population (MFP&ED, 1996 in Mwebaze, 2008).

2.2.1. Soils and soil fertility

There are 18 main geomorphic units in Uganda (Aniku, 2001). Fertility of soils is rated according to the Reconnaissance Soil Survey of Uganda (Chenery, 1960) and distinguished into a number of categories ranging from soils with productivity greater than medium down to soils with low or nil productivity. For Uganda surface soils an organic matter content above three percent is considered adequate (Foster, 1971 in Ssali, 2001).

2.2.2. Climate & water

Temperatures show little variation throughout the year with maxima ranging between 25°C and 31°C for most areas. Most sunshine is received in the north-east and least in the south-west of the country (Komutunga & Musiitwa, 2001).

Rainfall distribution has been divided into three categories (in brackets: percentage of total land area) (Mwebaze, 2008): High: over 1 750 mm p.a. (4%), Moderate: 1 000 - 1 750 mm p.a. (70%), Low: under 1 000 mm p.a. (26%)

On average the country receives 1000 mm of rain per annum. The variation of rainfall is large over the country ranging from 625 mm to 2000 mm (Kahangire & Lubanga, 2001). Rainfall distribution in Southern Uganda is bimodal, allowing two crops annually, and adequate grazing for livestock throughout the year. To the north, two rainy seasons gradually merge into one (Mwebaze, 2008). Areas north of latitude 3°N experience a unimodal rainfall distribution (Komutunga & Musiitwa, 2001). Dry periods at the end of the year become longer, with annual rainfall ranging between 900 mm and 1 300 mm, this restricts the range of crops that can be grown but favours extensive livestock production (Mwebaze, 2008).

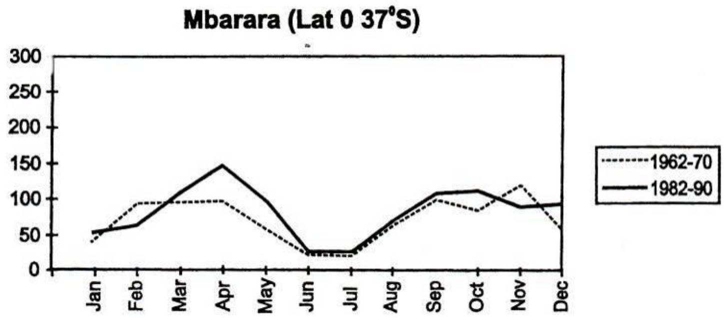

Fig. 3 Seasonal rainfall pattern Mbarara (Komutunga & Musiitwa in Mukiibi, 2001)

Uganda is blessed with abundant water resources compared with most countries in Africa. Surface sources of water are dominated by the River Nile and associated Great Lakes Victoria, Kyoga, Albert, Edward and George. Surface impounding reservoirs for water for livestock have been constructed between 1948 and 1970 but afterwards no operation and maintenance was in existence and currently most of these reservoirs are in dire need of repair. Less than 30000 ha of arable land are irrigated mostly based on old pilot schemes while irrigation in Uganda is in an early stages of redevelopment (Kahangire & Lubanga, 2001).

2.2.3. Vegetation

Vegetation types vary greatly associated with a wide range of physiographic and ecological conditions which include well-watered tropical zones, zones with marked seasonality, semi-arid areas and mountains permanently covered with snow (Aluma, 2001).

The five major vegetation types, described by Aluma (2001), are: 1) Mountain vegetation consisting of moorland, heath and forest, 2) Medium altitude forests, 3) Wetland vegetation, 4) Savanna woodlands consisting of forest mosaics, *Acacia* savanna, *Combretum* savanna, *Butyrospermum* savanna and thickets and 5) Savanna grassland.

2.2.4. Agro-ecological zones

Influence of soils, topography and climate on farming systems has led to classification into 7 broad agro-ecological zones (Fig. 4) (Parsons in Jameson, 1970; Mwebaze, 2008).

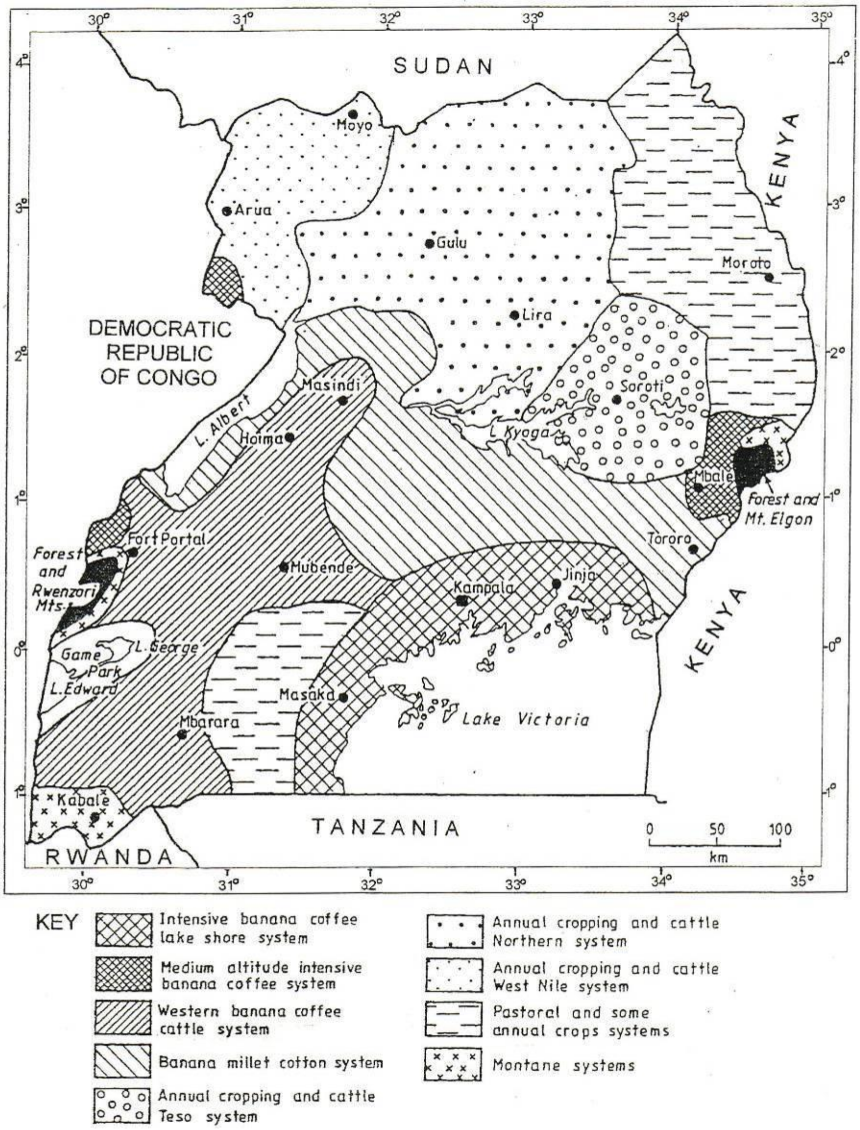

Fig. 4 Agroecological zones of Uganda (Mugerwa, 2001)

Zones are based on soils, topography, rainfall and major crops grown (Mwebaze, 2008): 1) banana-coffee system, 2) banana-millet-cotton system, 3) montane system, 4) Teso system, 5) Northern system, 6) West Nile system and 7) Pastoral system (Musiitwa & Komutunga, 2001).

Mugerwa (2001) defines farming systems slightly different: 1) Intensive banana-coffee lake shore system, 2) Medium altitude intensive banana-coffee system, 3) Western banana-coffee-cattle system, 4) Banana-millet-cotton system, 5) Annual cropping and cattle Teso system, 6) Annual cropping and cattle Northern syten, 7) Annual cropping and cattle West nile system, 8) Pastoral and some annual crops system and 9) Montane system.

2.3. Ruminant livestock production systems in Uganda

Livestock is an integral part of agriculture in most areas of Uganda. Major livestock species include cattle, sheep, goats, pigs, rabbits and poultry. It is estimated that mixed farming, small holders and pastoralists own over 90% of cattle and all small ruminant and non-ruminant stock. They produce the bulk of domestic milk and slaughter animals. From an economic point of view, cattle are the most important livestock with significant contributions of goats and sheep (Mwebaze, 2008). One third of the country is denied to most forms of livestock keeping due to the tsetse fly which transmits trypanosomiasis. There are also other epidemic livestock diseases like rinderpest, bovine pleuro-pneumonia, East Coast Fever, foot-and-mouth-disease and brucellosis (Mahadevan & Parsons, 1970).

Production systems have evolved over time to suit agro-ecological zones and socio-economic setting. Two main types of livestock systems have been defined. Traditional system, with minimal inputs and correspondingly small outputs which depend on natural grazing and local breeds. The other type are improved systems which have some investment (such as fencing, pasture and grassland improvement, provision of water, breed upgrading and others) (Mwebaze, 2008).

Following grazing methods are applied in livestock production systems: communal/pastoral system, tethering, enclosed ranching, fenced dairy farms and zero grazing (Mwebaze, 2008). Indigenous cattle of three main types: long-horned Sanga (with Ankole as sole representative), short-horned Zebu (East African Short Horn Zebu) and Nganda (intermediate cattle breed between the former types (Mahadevan & Parsons, 1970 and Twinamasiko, 2001) .

2.3.1. Dairy production in Uganda

Mahadevan & Parsons (1970) stated a vast existing potential for an increase in milk production. In their opinion exploitation would depend on continued disease control, suitable markets and improved animal husbandry practises. Back then improvement of animal husbandry practices was hindered by traditional livestock keeping systems. Average milk production for Nganda cattle was 1032l (227gal) per lactation. Ankole cattle (under superior conditions on government farms) could yield between approximately 900l and 1140l (200-250gal) per lactation (Mahadevan & Parsons, 1970). Ankole cows produce on average 2l of milk per day (Okello, 2006 in Grimaud et al., 2006).

Until the 1950s selective breeding within indigenous cattle was practised to increase milk production. It was believed, that careful selection, was the most constructive and successful longe-term solution for livestock breeding. Crossing or upgrading with European [therefore exotic] breeds was regarded highly unlikely to succeed in the long run (Mahadevan & Parsons, 1970).

The increase in milk production was too slow for Uganda´s demand. That´s why in 1959 introduction of European milk breeds was started with. At the same time insemiation of indigenous cattle with semen of exotic breeds was begun. The introduction of European type cattle was facilitated by the adoption of land enclosure (Mahadevan & Parsons, 1970). A prerequisite for the introduction of exotics and crossbred animals was eradication of ticks due to tick-borne diseases. Following requirements were seen as essential (Mahadevan & Parsons, 1970): an adequate, stockproof fence, independent water supplies for each farm, sufficient grazing through the year, effective spray or dip and effective quarantine systems to ensure ticks were not re-introduced.

In the 1960s large scale beef ranching in western Uganda and introduction of Holstein Friesian as breed of choice for milk production took place. In the Ankole-Masaka Ranching scheme 625 square miles (approx.1620km²) were converted into 125 ranches of 3000 acres (1215ha) each. Land was fenced, valley tanks built and ranchers were provided with a central kraal, a spray race and cattle handling facilities. Holstein Friesians had come to stay as the outstanding dairy breed (Mahadevan & Parsons, 1970).

In recent times the number of (dairy) cattle has risen steadily. From 1984 to 1996 indigenous cattle numbers have increased by 13% and numbers of improved breeds have increased by 175% (Twinamasiko, 2001).

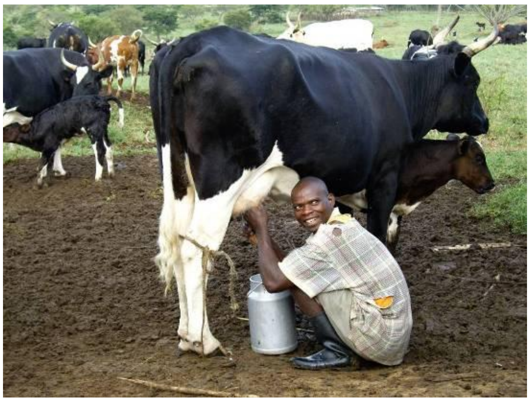

Fig. 5 Milking a Ankole X Holstein Friesian cow

Fig. 6 Milk transport to local collection center

Milk production has increased from 36 million litres per year in 1970 (Mahadevan & Parsons, 1970) to 436 million litres in 1980 and to 571 million litres in 1996 (Twinamasiko, 2001). Causes of low milk production from tropical pastures include physiological stress for the cow (especially *bos taurus* breeds) caused by high temperatures which influence grazing behaviour and reduce nutrient intake (Mugerwa, 2001).

While facing serious constraints (lack of coordinated marketing, infrastructure, outputs, breeding stock, management skills, extension services; diseases and market size among others) the dairy sector is still viewed as an important sector. It is expected to offer opportunities for export, dairy products and, possibly, milk powder production (Twinamasiko, 2001).

2.4. Grassland communities of Uganda

Uganda has six major natural grassland communities which are associated with farming systems and agro-ecological zones (Fig. 7). Natural pastures are fairly productive and contain many desirable grasses and browse plants. They are a valuable natural resource, which, if well managed, can be very productive. (Mwebaze, 2008). The six major natural grassland communities are (Mwebaze, 2008):

2.4.1. Pennisetum purpureum grassland

A coarse, fire climax grassland dominated by *Pennisetum purpureum* (Elephant grass[1]) occurs on fertile soils in better watered areas (rainfall between 1000mm and 2000mm p.a.) between 1000m and 2000m a.s.l.. Rainfall is well distributed without marked dry season (Horrell & Tilney, 1970, Sabiiti, 2001 and Mwebaze, 2008). Other grasses of grazing value associated are *Brachiaria spp, Cynodon nlemfuensis* (star grass)*, Panicum maximum* (Guinea grass) and *Hyparrhenia rufa* (Thaching grass). The only native legume is *Neonotonia wightii* (Glycine). Introduced legumes include *Centrosema pubescens* (Centro)*,*

---

[1] Common names of species taken from: Cook, 2005; USDA, NRCS, 2009 and Andersson, 2009. Common names only added at first appearance of species

Macroptilium atropurpureum (Siratro), *Desmodium intortum* (greenleaf desmodium), *D. uncinatum* (silverleaf desmodium). Fodder grasses used are *P. Purpureum* (Napier grass), *Tripsacum laxum (Guatemala grass)* and *Setaria splendid (Splendid bristlegrass).* Herbaceous legumes are *Lablab purpureus* (Lablab bean) and *Stizolobium spp*. Tree legumes in use include *Leucaena leucocephala* (Wild tamarinde), *Calliandra calothyrusus* (Calliandra) and *Sesbania sesban* (Egyptian pea) (Mwebaze, 2008). If continuously grazed *P. purpureum* is rapidly eaten out and replaced by a short sward containing *Brachiaria spp*, *Cynodon dactylon* (Bermudagrass) and other herbs. In lightly grazed areas *P. purpureum* rapidly becomes stemmy, overgrown and of little grazing value (Horrell & Tilney, 1970 and Sabiiti, 2001). Estimated stocking rate, according to Horrell & Tilney (1970), is one beast per 1.60ha - 3ha. Sabiiti (2001), citing Parsons (1960), estimated, 4-8 hectares per beast.

2.4.2. Moist *Hyparrhenia* grassland

A moist savanna community dominated by *Hyparrhenia rufa* and *Panicum maximum* which occurs on fertile soils with annual rainfall of 1000mm - 1500mm. Other common grasses are *Chloris gayana* (Rhodes grass), *Brachiaria* spp., *H. variabilis* and *Imperata cylindrica* var. *Africana* (Cogongrass). Most grasses and legumes suitable for this system are those mentioned in the grassland community above (Sabiiti, 2001 and Mwebaze, 2008). *Hyparrhenia cymbari*a (Coloured hood grass) is prominent in limited areas of higher altitude, under moist conditions, in south-western and north-eastern Uganda (Horrell & Tilney, 1970 and Sabiiti, 2001). Carrying capacity is estimated at 5ha per H/C (Sabiiti, 2001).

2.4.3. Dry *Hyparrhenia* grassland

Found where growing conditions are not as favourable as for moist *Hyparrhenia* grassland. Dominant species are *Hyparrhenia filipendula* (Fine hood grass) and *Hyparrhenia dissoluta* in dry *Combetrum* savannas (Mwebaze, 2008). *H. filipendula* is a less usefull grazing grass than *H. rufa* (Horrell & Tilney, 1970). Other grasses are *Setaria sphacelata* (Broadleaf setaria), *Themeda triandra* (Red oat grass), *Cenchrus ciliaris* (buffelgrass), *Cynodon nlemfuensis* and grasses of minor feed value like *Andropogon gayanus* (Gamba grass), *A. schriensis* and *Heteropogon contortus* (Pili grass). Quality of herbage is rather low, especially during dry season (Mwebaze, 2008). Carrying capacities for dry *Hyparrhenia* areas are estimated by Horrell & Tilney (1970) at 2 ha per beast during rainy season and 3ha - 20ha per beast during dry season. A later source estimates 7 ha per H/C (Sabiiti, 2001).

2.4.4. Themeda triandra grassland

Most important constituent of grass communities in pastoral rangelands of south-western and north-eastern Uganda (Sabiiti, 2001). Associated with degraded forms dominate by coarse, unpalatable species (Horrell & Tilney, 1970 and Sabiiti, 2001). A fire-climax community of southern cattle corridor stretching from the shores of Lake Kyoga to the Tanzanian border. Very nutritious when young. It occurs in savanna communities associated with *Acacia* spp. on light textured soils in altitudes of 1200m (rainfall between 769 mm and 1120mm) (Horrell & Tilney, 1970, Sabiiti, 2001 and Mwebaze, 2008). Some *Acacia* trees, are important fodder. Shade loving grasses like *Brachiaria brizantha* (beard grass) and *Panicum maximum* thrive amongst *Acacia*, provided that trees are scattered. Other important grasses are *Chloris gayana, Cynodon nlemfuensis*, and *Setaria sphacelata*. Grazing value is reduced by weeds (such as *Cymbopogon afronadus* (lemongrass) and *Imperata cylindrical* (speargrass). Some adapted forages include *Leucaena leucocephala, Stylosanthes spp.* (Stylo) and *Calliandra calothyrusus* (Mwebaze, 2008).

This grassland community falls into two main sub-divisions: Ankole grasslands in the south-west and Karamoja grasslands in the north east (Horrell & Tilney, 1970 and Sabiiti, 2001). Ankole grasslands were traditionally grazed by Bahima pastoralists (Horrell & Tilney, 1970 and Sabiiti, 2001). Frequent burning during dry season has been a feature of traditional management (Horrell & Tilney, 1970). Because of pressure on rangeland resources movement of livestock in traditional pastoral patterns is no longer feasible. Individualization of land rights has taken place. Grasslands have been invaded by shrubs, which have reduced grazeable land and suppressed palatable grasses like *Brachiaria brizantha*, *Setaria anceps* (Golden bristle grass) and *Cynodon dactylon*. (Sabiiti & Wein, 1991 in Sabiiti, 2001). Carrying capacity is estimated 3ha - 7 ha per beast by Horrell & Tilney (1970) and in more recent sources 8 - 18ha per beast (Sabiiti, 2001).

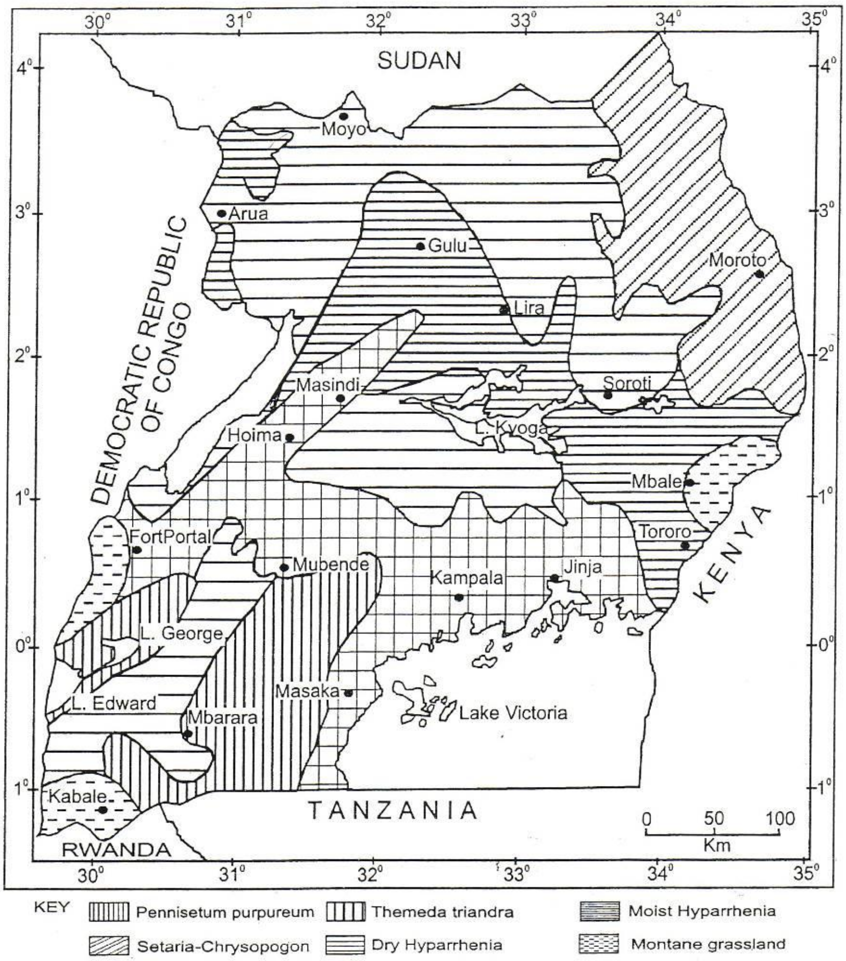

Fig. 7 Natural grasslands in Uganda (Sabiiti, 2001)

In Karamoja *Themeda triandra* areas lie between wetter *Hyparrhenia* grassland to the west and drier *Setaria incrassata* (purple pidgeon grass) to the east. Rainfall is unimodal and falling mainly as intense storms with low ground acceptance. Dry season is long and severe (Horrell & Tilney, 1970 and Sabiiti, 2001). Carrying capacity during rainy season is estimated from 3ha – 7ha per beast by Horrell & Tilney (1970) and from 8ha – 18ha per beast (Sabiiti, 2001). During dry season estimates stretch from 4ha - 16ha per beast (Horrell & Tilney 1970) to 10 - 40 ha per beast (Sabiiti, 2001). North-eastern *Themeda* areas were traditionally dry weather grazing grounds for Karamoja herdsmen. Herbage was burnt annual, prior to grazing (Wilson, 1962 in Horrell & Tilney, 1970).

In both regions shrub encroachment and subsequent reduction of grazeable land has drastically reduced carrying capacity (Sabiiti, 2001).

2.4.5. Setaria-Chrysopogon grassland

This community covers substantial areas of the north-eastern part of the country. Dominated by *Setaria incrassata,* characteristic for clay plains of Karamoja. Common grasses are *Themeda triandra, Sorghum* spp., *Eriochloa nubica* (Cupgrass) and *Dichanthium papillosum* (Medio bluestem). Annual rainfall is 750mm - 1000mm. Further east, under rainfalls of 350mm - 500mm, *Chrysopogon* clay steppes of Karamoja, suitable to moderate grazing, are found. Bush and thickets occur at altitudes of 1200m - 2000m on shallow soils with rainfall of 300mm - 850mm (Mwebaze, 2008).

2.4.6. Montane grassland

Grass savannahs with abundant *Andropogon distachyus* (Long beard grass), *Cenchrus validus, Exotheca abyssinica* (Exotheca) and *Hyparrhenia cymbaria* (Buffel grass) have developed in altitudes of 1680m - 3000m (Horrell & Tilney, 1970 and Sabiiti, 2001, Mwebaze, 2008) and can be divided into two sub-types:

First subtype are *Panicum clandestinum* (Dear tongue grass) areas found on fertile, volcanic soils under moist conditions. Pasture land is close to cultivated land. Under grazing a dense, closely cropped sward develops, dominated by *P. clandestinum*. Burning is normally not practiced. Carrying capacity is estimated at 0.4ha - 0.8ha per beast (Horrell & Tilney, 1970). The *P. clandestinum* grasslands contain a natural clover, *Trifolium semipilosum* (Kenya clover), very compatible against grasses (Mwebaze, 2008).

Second sub-type are Karamoja highland areas found from 2100 m - 3000 m. They consist of tufted grasses *Exotheca abyssinica*, *Cymbopogon validus* (Giant turpentine grass, Ceylon citronella) and Setaria *spacelatea* accompanied by herbs. Rainfall and soil moisture are better than in surrounding country, but dry season is long and grass productivity low. Burning occurs occasionally, grazing only seasonal (Horrell & Tilney, 1970).

2.4.7. Other grassland communities

Sub-alpine grasslands above 3000m and marginal grasslands (Horrell & Tilney, 1970).

2.5. Pasture resources in Uganda

95% of ruminant livestock depend on natural/native pastures. Planted grasslands occupy a very small area (mainly fenced or zero grazing farms). The term “pasture” describes land entailing species of grass, multi-purpose trees, shrubs, legumes [and dicotyledonous herbs] dotted with shade trees that is not under frequent arable farming but mainly used to rear livestock (Waigambi, 1993 in Kagoda, 2001). Uganda is endowed with good to excellent forage resources relative to other East African and Sub Saharan countries (Mugerwa, 2001). A different source emphasizes 99% of cattle graze on poor pastures with low productivity (Sabiiti, 2001).

According to Horrell & Tilney (1970) grassland can be divided into two categories: natural or permanent grassland (semi-natural under prevailing environmental conditions) and artificial, temporary or planted grassland (direct result of sowing or planting, ley).

Almost all grassland vegetation in Uganda belongs to the first category (Horrell & Tilney, 1970). Natural grassland usually occurs as prominent herb layer between savanna vegetation occupying ground cover between trees and shrubs of varying density. Tilney (1970) referred to Uganda´s pastures as „volunteer pastures“. Derived from naturally developed vegetation under influence of grazing and burning. A characteristic feature of many tropical pastures is, that annual transpiration is limited by annual rainfall and plants comprising pasture must either be able to withstand draught, sometimes for considerable periods of time or else be rapid growing and rapid seeding annuals (Davies and Skidmore, 1989 in Kagoda, 2001).

Fig. 8 Typical pasture in southwest Uganda I

Fig. 9 Typical pasture in southwest Uganda II

Quality rather than quantity is the major deficiency. Although overall fairly productive and containing many desirable grass species, legume content is extremely low, causing digestibility and protein to fall short of requirements for high producing animals, especially dairy cattle (Mwebaze, 2008). Present poor utilization and low productivity is largely attributed to lack of well articulated management guidelines for these grasslands (Mwebaze, 2008). With proper agronomic practices and pasture utilization good forage yields and animal production levels can be achieved. (Mugerwa, 2001).

Indigenous grasses are, in general, better adapted than introduced species with the possible exceptions of *Tripiscum laxum* and *Paspalum notatum* (Bahia grass) (Mugerwa, 2001). Indigenous species include: *Panicum maximum, Brachiaria ruziziensis* (Congo signal grass), *Chloris gayana, Hyparrhenia rufa, Pennisetum clandestinum* (Kikuyu grass), *Setaria anceps* and *Pennisetum purpureum* (Mwebaze, 2008).

Pennisetum purpureum is the only indigenous fodder grass. New superior varieties of *P. purpureum* have been developed. Introduced fodder grasses, which have been tested, evaluated and adopted in various agro-ecological zones, are *Tripsacum laxum* and *Setaria splendida* (Mwebaze, 2008).

The only major indigenous legume evaluated in detail which has shown great potential is *Neonotonia wightii* (glycine) (Mugerwa, 2001 and Mwebaze, 2008). A variety of fodder shrubs and leguminous trees are used to supply feed (Mugerwa, 2001).

During the 1970s research on various topics related to pastures took place and recommentdations for farmers were issued. But since 1974 only sporadic pasture research has taken place (Mugerwa, 2001). Some nutritional and yield studies have been conducted, mainly on experimental stations. Little is known about species´ relative contribution to overall feed value of grasslands. Public and private efforts are geared towards improving natural pastures by removing weeds and oversowing with legumes. Farmers, particularly dairy farmers, are establishing grass-legume pastures (Mwebaze, 2008).

2.5.1. Range management and utilization

Rangelands are used as rough grazing for livestock but also form part of land under rest from arable cropping (Horrell & Tilney, 1970). Productivity of rangelands is generally low. There are two grazing systems common in Uganda: communal grazing (pastoral resources are common property) or grazing on fenced farms (individualization of grazing resources). Different methods of grazing are applied: continuous grazing, rotational grazing and deferred grazing (stock grazes in one area, leaving the rest of the pasture to grow; this pasture is used during critical times) (Sabiiti, 2001).

Burning used to take place once or twice a year during dry season on most natural grasslands (Horrell & Tilney, 1970). Long term management of rangelands aims at preserving palatable, perennial pasture species in comparison to annual pasture species less sensitive to unreliable climatic conditions (Boer & Stafford Smith, 2003). Grazing of livestock and associated management practices, like fire, have been causing major changes in productivity and composition of rangeland vegetation (Milchunas & Lauenroth, 1993 and Friedel, 1997 in Boer & Stafford Smith, 2003). A commonly observed loss of perennial forage species and an increasing abundance of woody plants have been noticed as impacts of change in grazing and fire regimes (Boer & Stafford Smith, 2003). Changes may involve disappearance or invasion of plant communities and life forms (Landsberg et al., 1999).

A number of ways by which farmers can improve their rangeland properties are known: clearing of land (fire, mechanical removal of weeds (Fig. 10), integrated control systems), fencing, provision and management of water supplies (Fig. 11), oversowing and reseeding and/or control of stocking rates (Jameson, 1970 and Sabiiti, 2001).

Control of weeds, poisonous plants and bush regrowth is an important practice which can greatly enhance pasture productivity (Mugerwa, 2001). Improvement of pastures under ranching systems should concentrate on improving fences, repairing dips, improving water supplies, changing herd structure, genetic improvement, health management and animal husbandry. Pasture management on these ranches should concentrated on adjusting stocking rates, managing bush regrowth, removing poisonous plants and weeds and fire control. Fur further improvement pastures could be oversown with legumes (Mugerwa, 2001).

Fig. 10 Pasture improvement by bush clearing

Fig. 11 Improved supply of water by construction of valley dams

2.5.2. Problems for pasture based production in Uganda

Several problems place constraints on farmers producing on pasture in Uganda and hinder them from increasing their production.The major problem in feeding tropical livestock is not balancing nutrients, or complicated rationing, but finding enough feedstuff (Chamberlain, 1989).

Weeds in pastures increase in abundance by faulty management. Weeds decrease quantity and quality of pastures (Tilney, 1970 and Oryokot, 2001). Pasture weeds are often woody (*Acacia hockii*) succulents or poisonous (Nightshade (S*olanum incanum))* (Tilney, 1970 and Oryokot, 2001). Animals may ingest poisonous plants resulting in direct economic loss when animals die (Oryokot, 2001). Quality of livestock products may be reduced as off-flavours may be imparted for instance to milk when certain weeds are eaten. (Oryokot, 2001). Fibrous and unpalatable grasses are troublesome (Tilney, 1970 and Oryokot, 2001) (Fig. 12).

Overgrazing has led to degradation of rangelands through vegetation change and soil erosion (Twinamasiko, 2001). Stock numbers are normally not reduced during dry seasons and condition of animals usually deteriorates depending on local grazing pressure and severity of the dry spells (Horrell & Tilney, 1970) (Fig. 13). Carrying capacities for native pastures can only be guessed, due to lack of scientific studies relating animal productivity to quality forage. To increase pasture productivity an elucidation of carrying capacities in oder to determine optimum stocking rates is needed. This should prevent further environmental degradation (Mugerwa, 2001).

Pastures in Uganda have an extremely low legume content leading to insufficiency of pastures for high producing animals (Mugerwa, 2001). Another problem for farmers who want to improve pastures is lack of good pasture seed and porper grassland management (Mugerwa, 2001).

The insufficient availability of water for livestock, and human demand, in rural areas is another problem farmers face (Sabiiti, 2001).

Shrubs may affect grassland plants negatively by competition, positively by serving as grazing refuge, or neutrally (Pihlgren & Lennartsson, 2008). Rangeland deterioration, due to shrub encroachment, is an important factor affecting rangeland utilization in Uganda (Mugasi, 1996 in Sabiiti, 2001). Grazeable land has been reduced and palatable grasses have been surpressed. Shrubs have become strongly interlocked with *Acacia* trees, that most affected areas have become inaccessible to cattle (Boonman, 1993 in Sabiiti, 2001). The invasion of shrubs has reached alarming proportions (Harrington, 1974 in Sabiiti, 2001). In certain regions one source estimates the rate of herbage made inaccessible to cattle with three quarters of total herbage availiable (Harker, 1959).
There are several conflicting views as to what Increases the number of trees, shrubs and thickets. Following reasons are suggested: low soil fertility, termitaria, reduction of cattle and human population, grazing/browsing pressure, changes in fire regime insufficient availiability of water and livestock diseases (Sabiiti, 2001).

Change of fire and grazing regimes has led to major changes in productivity and composition of rangelands. It often results in loss of perennial forage species and increasing abundance of woody plants (Boer & Stafford Smith, 2003). Burning and grazing regime have a high impact on growth form of *Acacia* hockii and therefore on accessability of herbage. Fire has shown to encourage *A.hockii* to grow in tree form which may be confirming the hypothesis, that changes in fire regime play a role in increasing growth of shrubs (Harker, 1959). It has also been proved that fire stimulates germination of *Acacia* seeds (Sabiiti & Wein, 1987).

Once established, *A. hockii* is hard to kill (Harker, 1959). The canopy shade restricts light and decreases grass growth. Heavy grazing and browsing can control a given mixture of *Acacia* trees (Sabiiti & Wein, 1987). But *A.hockii*, as a leguminous, deep rooted tree may also be beneficial to cattle. Young leaves are occasionally browsed and tree litter enhances soil fertility resulting in better pasture quality around trunks (Harker, 1959).

Shrubs, spiny species or toxic plants can also have positive effects on herbaceous pasture plants by providing protection from grazing (Rebollo et al., 2002).

Fig. 12 Pasture area almost solely covered with weeds (Cymbopogon afronardus)

Fig. 13 Ankole on very poor pasture at the end of dry season in Luwero area

Trees may affect productivity of grazing systems by altering pasture productivity, quality, or species composition (Jackson & Ash, 2001). Trees affect growth of pasture plants around them by altering availability of resources (Scholes & Walker, 1993 in Jackson & Ash, 2001). Radiation and precipitation inputs may be reduced due to interception by tree canopies. Soil moisture status, may be enhanced due to effects of canopy and litter layer on evapotranspiration. Tree´s uptake of water may reduce water availability for herbaceous plants. Soil physical and chemical conditions around trees may be enhanced, while allelopathic effects may suppress herbaceous layer growth (Jackson & Ash, 2001). During dry season nutritive quality of trees and shrubs often remains higher than quality of grasses. Trees and shrubs remain green and can sustain livestock production as supplement to grass during dry season. Leguminous trees and shrubs conserve water sheds, provide wind breakers and soil erosion barriers and maintain soil fertility (Sabiiti, 2001 in Mukiibi, 2001b). Provision of shade [as under trees] is essential to welfare of farm animals in areas where temperature during summer exceeds 24°C (Silanikove, 2000). Access to shade in a pasture-based system improves animal well-being (Valtorta et al., 1997). Tree foliage is increasingly recognized as a potentially high quality feed resource for ruminants, particularly to supply crude protein (Leng, 1997).

2.6. Nutritive qualities of pasture in Uganda

General nutritional value of tropical rangeland is low compared to temperate pastures (Long et al., 1969). Tropical environments are characterized by higher temperatures, longer nights during growing seasons and C_4 grasses. This leads to generally lower nutritive value, greater lignification, low soluble carbohydrate and high cell wall levels (Mihreteab, 2000).

Tropical grasses have a high proportion of lignified and suberized cells resistant to breakdown during digestion. This feature, together with the propensity of tropical grasses to progress rapidly towards maturity, may be associated with low digestibility and low intake. Temperate grasses contain more moisture, more crude protein and a higher amount of other nutrients (Mihreteab, 2000). Pasture quality varies between sites, seaons and is influenced by environmental factors. Three factors, and their interactions, have a considerable effect on pasture quality: burning, rainfall pattern and grazing pressure (Long et al., 1969). Factors affecting chemical composition of forages can further be divided into:

plant factors (species and cultivars), agroclimatic factors (humidity, temperature, soil, etc), cultivation practices (fertilization, irrigation, weed control,etc), harvesting or grazing schedule (stage of harvest, grazing intensity,etc) and processing and preservation practices (Mihreteab, 2000).

Metabolizable energy for 7 tropical grasses selected by Mihreteab (2000) reached a mean of 10 MJ/kg DM (9.12 MJ/kgDM to 10.97 MJ/kgDM). Annual consumption of 1 livestock unit (LU = 350kg) is estimated to be 3200kg. Estimated carrying capacities range between 1.20 LU/ha and 3.87ha with a mean estimated stocking rate of 1.82 LU/ha (MAAIF, 1997 in Mugerwa, 2001).

Estimations for pastoral rangelands in Uganda determine an average annual dry matter yield per hectare between 1.7 t/ha and 3.9t/ha with a mean annual dry matter yield around 3.2 t/ha (Mugerwa, 2001). According to a local study season has a significant effect on pasture dry matter yield. During long dry season mean dry matter yield was 1407 kg/ha. During long rainy season mean dry matter yield rose to 3045 kg/ha (Kagoda, 2001). Dry matter content of tropical grasses has been analysed for 15 species by Juarez Lagunes et al. (1999). Mean dry matter yield was 22.3% ranging from 15.2% to 28% of total fresh mass. For 7 species of tropical grasses, analyzed by Mihreteab (2000), mean dry matter content was 28.84% ranging from 21.2% to 32.3%. Daily dry matter intake increases with milk production (Chamberlain, 1989) (Table 2).

Table 2. Increasing dry matter intake with increasing milk production (Chamberlain, 1989)

	Milk yield per day, l (cow: 450kg)				
	5	10	15	20	30
DM intake, kg	11.8	12.3	12.8	13.3	14.3

Structural carbohydrates provide most energy in tropical grasses (Juarez Lagunes et al., 1999). Tropical grasses contain high proportions of crude fibre from an early stage of growth. In a survey of 72 tropical grass species crude fibre content ranged from 24.5% to 41.66%. Crude fibre content of major contributors to pastures surveyed ranged from 30.31% to 37.18% (Long et al., 1969). Juarez Lagunes et al., (1999) analysed 15 tropical grass species and determined mean neutral detergent fibre (NDF) content at 70.55% of total dry matter ranging from 63.5% to 74.9%. Mihreteab (2000) measured a mean NDF of 65.3% ranging from 53,1% to 77,47%. Kagoda (2001) found out that NDF of pastures in south-western Uganda varies according to seasons. Mean annual NDF content of 69,5% was measured with maximum during long dry season at 73.8% and minimum during long rains at 64,1%.

Grasses of tropical and suptropical origin accumulate starches in their vegetative tissue rather than fructosans accumulated in greater amounts by grasses of temperate origin (Mihreteab, 2000). Starch equivalent intake by cattle grazing on pasture in Uganda is satisfactory for maintenance and some degree of production throughout the year (Brendon & Wilson, 1963 and Juko & Brendon, 1961 in Dradu & Harrington, 1972; Long et al., 1969).

Protein equivalent of pasture in Uganda can frequently be limiting for an extended period of time (Brendon & Wilson, 1963 and Juko & Brendon, 1961 in Dradu & Harrington, 1972; Long et al., 1969). Grasses with high protein values do not make a significant contribution to pasture composition in Uganda´s fire climax grasslands (Dradu & Harrington, 1972). Analysis of grasses in Ankole, by Long et al (1969), resulted in a generally low crude protein content in all but a few grasses collected. Compared to temperate zone pastures, with crude protein contents around 20% (Wienmann, 1955), average crude protein contents measured by Long et al. (1969) was 6.24%. Juarez Lagunes et al (1999) measured mean crude protein content of 8%. Mihreteab (2000) measured mean crude protein content of 10.3%.

Other plant groups, like dicotyledonous herbs [or legumes] have higher crude protein contents than most tropical grasses (Dradu & Harrington, 1972). Legume content of natural pastures in Uganda is extremely low [little to no legume content (Stobbs, 1975 in Sabiiti, 2001); 10% legumes (Jameson 1970)]. Digestibility and protein in several locations falls short of requirements for high producing animals, especially dairy cattle (Mwebaze, 2008). C_3 forage plants, such as legumes, do not compete well with C_4 grasses (Mihreteab, 2000).

Cattle are highly selective in their choice of herbage. It can be assumed that highly nutritious plants contribute a greater proportion to plant matter consumed than their relative frequency would suggest (Long et al., 1969). Preference of ruminants for leaf ensures selection of high quality diets (Norton, 1981 in Mihreteab, 2000).

In regions with 2 rainy seasons, there is a seasonal variation in crude protein content (Dradu & Harrington, 1972, Kagoda, 2001). Kagoda (2001) measured mean annual crude protein content of 9.6%. During long dry season maximum mean crude protein content reached 10.8%. Mimimum mean crude protein content was recorded during short rains with 8.7%. During drought soil nitrogen accumulates and is utilized by plants when moisture becomes availiable (Millbank, 1956 in Dradu & Harrington, 1972). Acculmulation of soil nitrogen reaches a higher peak after long dry season than after short dry season. Not only accumulation of soil nitrogen but also fragmentation and crushing of dry herbage is higher during long dry season. This makes it easier for animals to access freshly grown herbage and results in a higher intake of protein after long dry season (Dradu & Harrington, 1972).

Lipid content of leaf tissue ranges from 3% to 10% and generally declines with maturity (Mihreteab, 2000). Mean lipid content of 15 tropical grass species was measured at 1.85% (Juarez Lagunes et al, 1999).

Mean phosphorus content of local tropical pasture was calculated at 0.33% (0.19% - 0.45%) (Mihreteab, 2000). Most tropical grasses have a mean level of phosphorus of 0.29% (Minson, 1990 in Rubanza et al., 2005). Tropical forage of other regions had a mean phosphorus content of 0.42% (0.27% - 0.57%) (Rubanza et al., 2005).

Calcium content of tropical local grasses reached a mean of 0.32% (0.21% to 0.41%) (Mihreteab, 2000). Forage from Tanzania had a mean calcium content of 0.69% (Rubanza et al., 2005). Calcium content in most tropical grasses ranges from 3.3 - 4.7g/kg DM (0.33%-0.47%) (Minson, 1990 in Rubanza et al., 2005).

Further mean mineral contents for tropical forage determined by Rubanza et al (2005) were: Magnesium: 2.2g/kg DM, Sulphur: 2.1g/kg DM, Iron: 505mg/kg DM, Copper: 5.1mg/kg DM, Cobalt: 0.35mg/kg DM, Mangan: 102.2mg/kg DM, Zinc: 30.12mg/kg DM and Molybden: 56.9mg/kg DM.

Legumes in a local study reached following mean values (percentage of total dry matter): 29,75% dry matter, 17.22% crude protein, 45.59% NDF, 31.99% calcium, 0.28% phosphorus and mean metabolizable energy was 10.5 MJ/kgDM (Mihreteab, 2000).

2.7. Plants under the influence of grazing

“Avoidance and tolerance are the two means by which plants cope with herbivores” (Milchunas & Noy-Meir, 2002). Grazing is a highly complex disturbance with both direct and indirect impacts on plant communities. Grazing has the potential to produce major shifts in species composition in some areas (Diaz et al., 1994 in Diaz et al., 1999).

Direct impacts include damage to plant parts through herbivory and trampling and immediate effects on community physical structure. Indirect impacts include a change of community composition, perturbation of soil and water processes which will affect plant competition and resource availability (McIntyre et al., 1999). Impacts of grazing vary with habitat attributes such as landscape variation, site productivity and dominant life forms (Friedel et al., 1988, McIntyre & Lavorel, 1994, McIntyre et al., 1995 and Milchunas et al., 1990 all in McIntyre et al., 1999).

Selectivity of grazers is a complicating factor. (McIntyre et al., 1999). Preference of grazers for certain plants can be influenced by individual plant traits (Briske, 1996 in McIntyre et al., 1999). The final selection of plants reflects the preference of individuals modified by available opportunities (Hodgson, 1979 in McIntyre et al., 1999).

According to Landsberg et al (1999) plant communities show different qualities when grazed under different intensity levels. Grazing is associated rather with loss of differetiation in species composition than loss in overall species. This means that dominance of certain species changes (Landsberg et al., 1999 and Lavorel et al., 1999). Species composition in different vegetation patches tends to converge as grazing intensity increases (Landsberg et al., 1999).

Evolutionary history of grazing is a more explanatory variable of composition and productivity change in plant communities than grazing intensity according to other sources (Milchunas and Lauenroth, 1993 in Diaz et al, 1999). Floras may show little response to disturbances [like grazing] that have been present for a long time (Lavorel et al., 1999).

Persistence under grazing can be considered as net expression of several traits which, in combination, allow plants to persist grazing regimes by avoiding damage at critical times or by tolerating damage sufficiently to allow re-growth or recruitment (McIntyre et al., 1999). The range of traits, potentially relevant to persistence under grazing, is extremely wide (McIntyre et al., 1999). Traits have proven to be elusive (Briske 1999 in Gaucherand & Lavorel, 2007). A number of strategies, associated with different trait syndromes, are used to avoid or resist defoliation (Landsberg et al., 1999).

Most traits related to grazing are not relevant to annual grasses, as the majority does not have resources to develop specific defense structures or compounds. Certain attributes influence sensitivity to grazing, but on many occaisons it is not only inherent traits, but interactions with other species and herbivores which determines grazers impact (McIntyre et al., 1999).

2.7.1. Growth

Capacity for plants to change morphology in response to defoliation is important to withstand grazing (McIntyre et al., 1999). Traits associates include (Table 3):

Table 3. Plant traits associated with response to grazing

trait	source
growth from	Cornelissen et al., 2003b, Lavorel et al., 1999
lateral spread	Landsberg et al., 1999, McIntyre & Lavorel, 2001, Lavorel et al., 1999
plant height	McIntyre et al., 1999, Landsberg et al., 1999, Lavorel et al., 1999, Cornelissen et al., 2003b, McIntyre & Lavorel 2001, Gaucherand & Lavorel, 2007
changing internode length	McIntyre et al., 1999
plasticity of habit	McIntyre et al., 1999, Landsberg et al., 1999, McIntyre & Lavorel, 2001
canopy structure	Landsberg et al., 1999, Lavorel et al., 1999, McIntyre & Lavorel, 2001
regrowth potential	Landsberg et al 1999
habit	Landsberg et al., 1999

Tolerance can also be achieved through rapid vegetative growth or prolific seedling regeneration (McIntyre et al., 1999). Vegetative growth features include: intrinsic growth rate (McIntyre et al., 1999), number, position and phenology of meristems or regenerative buds (McIntyre et al., 1999, Landsberg et al., 1999), clonality/vegetative reproduction (Cornelissen et al., 2003b, Weiher et al., 1999, McIntyre & Lavorel, 2001), extent of stored reserves (McIntyre et al., 1999), developmental plasticity (McIntyre et al., 1999).

A number of leaf traits respond to to grazing (Table 4):

Table 4. Leaf traits responding to grazing

trait	source
specific leaf area	Cornelissen et al., 2003b, Landsberg et al., 1999
leaf size	McIntyre et al., 1999, Landsberg et al., 1999
leaf width	McIntyre & Lavorel, 2001
leaf palatability	Landsberg et al. 1999; McIntyre & Lavorel 2001 in Gaucherand & Lavorel, 2007
toughness	Landsberg et al., 1999
leaf dry matter content	Cornelissen et al., 2003b
leaf N and P concentration	Cornelissen et al., 2003b
leaf phenology	Cornelissen et al., 2003b
physical strength of leaves	Cornelissen et al., 2003b
leaf lifespan	Cornelissen et al., 2003b
leaf/stem ratio	Landsberg et al., 1999, McIntyre & Lavorel, 2001

2.7.2. Root traits

Among root traits influenced by grazing are: specific root length (Cornelissen et al., 2003b), root morphology (McIntyre & Lavorel, 2001), diameter of fine root (Cornelissen et al., 2003b), distribution of rooting depth, 95% rooting depth (Cornelissen et al., 2003b), nutrient uptake strategy (Cornelissen et al., 2003b).

2.7.3. Avoidance of damage

Avoidance of damage [caused by grazing] can be achieved through defence or escape. Defence includes traits that act as deterrance (e.g. secondary compounds) or structural traits. Traits associated with grazing are: prickliness/spinescence (McIntyre et al., 1999, Cornelissen et al., 2003b, Landsgerb et al., 1999), hairiness (McIntyre et al., 1999), waxes (McIntyre et al., 1999, Landsberg et al., 1999), scleropyhlly (McIntyre et al., 1999), silification (McIntyre et al., 1999) and coating of leaves (Landsberg et al., 1999).

Escape can be achieved in time and space. Traits conferring ability to escape are: vulnerability of flowering parts for grasses (inflorescence height/relative prominence) (McIntyre et al., 1999), distance of active buds from roots (McIntyre et al., 1999), height of shrubs relative to main herbivore grazing (McIntyre et al., 1999).

2.7.4. Seedling regeneration

Another strategy to persist grazing is rapid seedling regeneration (McIntyre et al., 1999). Several plant traits are connected with seedling regeneration are (Table 5).

Seed size is related to a wide range of adult and juvenile traits like plant size (Mazer, 1989 and Leishmann et al., 1995 both in McIntyre et al., 1999) and defoliation tolerance (Armstrong and Westoby, 1993 in McIntyre et al., 1999). Seed mass is a trait measured to assist describing dispersal distance, longevity in seed bank, establishment success and fecundity (Weiher et al., 1999, Cornelissen et al., 2003b). Seed shape can be used to relate to longevity in the seed bank (Weiher et al., 1999).

Table 5. Traits connected with seedling regeneration

trait	source
number/position of inflorescenses	McIntyre et al., 1999, Landsberg et al., 1999, McIntyre & Lavorel, 2001
seed size	Mazer, 1989 and Leishmann et al., 1995 both in McIntyre et al., 1999, McIntyre & Lavorel 2001, Gaucherand & Lavorel, 2007, Landsberg et al., 1999
seed number/fecundity	Landsberg et al., 1999, McIntyre et al., 1999, McIntyre & Lavorel, 2001
seed mass	Weiher et al., 1999, Cornelissen et al, 2003b
dispersal strategy	McIntyre et al., 1999, Landsberg et al., 1999, McIntyre & Lavorel, 2001
dormancy strategy	McIntyre et al., 1999
seasonality of germination	McIntyre et al., 1999, Landsberg et al., 1999
specifity of germination requirements	McIntyre et al., 1999
life span	Landsberg et al., 1999

2.7.5. Other traits

For shrubs and trees twig dry matter content and bark thickness have proven to be affected by grazing (Cornelissen et al., 2003b). Photosynthetic pathway, flammability and life form/life cycle (Landsberg et al., 1999, McIntyre & Lavorel, 2001) are influenced by disturbance (Cornelissen et al., 2003b).

2.7.6. Traits favoured by grazing

As a general trend disturbance [such as grazing] favour annuals (Grime 1977 in Lavorel et al., 1999, McIntyre et al., 1999) and small-statured, leafy plants (Noy-Meir et al., 1989, Fernandez-Ales, Laffarga, & Ortega, 1993 both in Lavorel et al., 1999, and McIntyre et al., 1999). Small size, prostrate habit, high plasticity and high re-growth potential, are associated with heavy grazing (Landsberg et al., 1999). Small seeds (Landsberg et al., 1999, Lavorel et al., 1999) and protected inflorescences (Lavorel et al., 1999) are promoted by grazing.

Grazed plots show a higher abundance of forbs with leafy stem canopy structure, flat habit, small size and high plasticity of canopy structure. Forbs with high dormancy are favoured by grazing. Forb species with light seeds are favoured by grazing at the expense of species with very light seeds [like legumes] (Lavorel et al., 1999). Grazing favours grass species of medium height and/or narrow lateral spread, protected inflorescence and medium dormancy (Lavorel et al., 1999).

2.7.7. Traits penalized by grazing

Many perennial forage species are sensitive to overgrazing (Wheaton, 1994 in Boer & Stafford Smith, 2003) This leads to local extinction and replacement by annual or unpalatable woody perennials (Hodgkinson, 1992 in Boer & Stafford Smith, 2003).

Exclosures from grazing showed an increase of forb species with erect habit, rosette canopy structure, large size and low plasticity of canopy structure. (Lavorel et al., 1999). Large size, low plasticity, low regrowth potential, erect tussock, wind dispersed seeds, warm season germination and intermediate branching habit are associated with light grazing. Low meristems, high fecunditiy and small leaves are associated with heavy grazing (Landsberg et al., 1999).

2.8. Selected plant traits

Following traits have been chosen to be measured during field work. Traits were chosen according to 3 conditions: 1) being affected by grazing, 2) possibility to assess traits without prior knowledge of botanical composition and 3) assessment possible with basic equipment

2.8.1. Plant height

Plant height is the shortest distance between the upper boundary of main photosynthetic tissue of a plant and ground level expressed in meters (Cornelissen et al, 2003b). Weiher et al. (1999) define it as difference between highest elevation of photosynthetic tissue and plant base. Westoby (1998 in Weiher et al., 1999) suggests, that plant height should be measured on top of general canopy, discounting exceptional individuals or branches and height recorded sould correspond with the upper 20% of leaf display. Finally Weiher et al. (1999) state: " As long as one is clear about how height was measured, the difference between the [latter] two methods will be small". Although they ad that in their opinion it is much simpler and clearer to measure height at the highest point of plant canopy. Plant height should be measured near the end of the growing season. Scapes and peduncles should not be included(Weiher et al., 1999).

This trait is associated with competitive vigour, whole plant fecundity and with time intervals plant species are given to grow between disturbances like grazing (Weiher et al., 1999, Cornelissen et al., 2003b). Plants display increasing vertical biomass density and height with decreasing disturbance intensity and/or increasing resource supply (Kleyer, 1999). According to a global study there is a significant association between the direction of response to grazing and plant height. Positive response of short plants and negative response of tall plants are reported most frequently in all systems. The general trend of positive response of short plants and negative response of tall plants was more marked in systems with a long history of grazing than in those with a short history (Diaz et al., 2001; Diaz, et al., 2007).

2.8.2. Reproductive height

Among traits conferring ability to escape is vulnerability of flowering parts for grasses (inflorescence height/relative prominence) (McIntyre et al., 1999). The higher, and more prominent inflorescences are, the more exposed they are to damage.

2.8.3. Leaf length and leaf width

These two traits were chosen to replace leaf size, which is harder to measure. It has been confirmed, that larger leaved species have longer leaf expansion times. Small leaved species have a lower level of loss of expanded leaf area. This might provide selection pressure towards reducing leaf expansion time, via reducing leaf size (Moles & Westoby, 2000).

Intense cattle grazing in productive natural grasslands has been proven to lead to an increase of species with small tender leaves (Diaz et al., 2001). Small leaves are a typical mechanism of grazing resistance by grazing avoidance (Briske, 1996).

2.8.4. Life form

McIntyre et al. (1999) divide plants into growth forms (grasses/sedges, forbs and shrubs) and further subdivide into annual and perennial life cycle, ending up with five terminal life form groups. Basis for these categories are that defining traits (growth, life cycle) tend to be those which also define functional classifications when all life forms are analysed as a single group (McIntyre et al., 1999).

A classification system has been designed by Raunkiaer (1934 in Cornelissen et al., 2003b). For identification a single, principal characteristic is used: relation of perenniating tissue to ground surface. Perenniating tissue refers to embryonic (meristematic) tissue that remains inactive during winter or dry season and resumes growth with a return of more favourable conditions. For species underlying unpredictable disturbances, e.g. peridodic grazing, position of buds or bud-forming tissue allows to understand the likelihood of their surviving such disturbances (Cornelissen et al., 2003b).

Landsberg et al (1999) used the term life form differently. They identified three different types of life forms which were: grasses, herbaceous forbs and woody forbs. Life form appears to have a large effect, as it is correlated with other functionally important traits such as plant size. (Landsberg et al., 1999). As categorical trait life form is assessed by field observation or descriptions and photos in literature (Cornelissen et al., 2003b). Variations in plant communites influence which life form groups are chosen for analysis (McIntyre et al., 1999). Lavorel et al. (1999) determined, six [life form] response groups a priori: grasses, small rosettes, lare rosettes, small species with leafy stems, large species with leafy stems and legumes.

2.8.5. Growth form

This trait is determined by canopy structure and canopy height.

Positioning of foliage may both be adaptations and responses to grazing. Rosettes and prostrate growth forms are associated with high grazing pressure by mammalian herbivores (Cornelissen et al., 2003b).

According to a global study of plant trait respose to grazing, there is a significant association between the direction of response to grazing and habit. In all systems erect plants tended to respond negatively to grazing, and prostrate plants tended to respond positively (Diaz, et al., 2007).

Growth form is a categorical trait and assessed by field observation or descriptions and photos in literature. There are 20 categories (Cornelissen et al., 2003b, Table 6).

Table 6. Growth form categories

growth form		description
1)	short basal	leaves < 0.5m long concentrated very close to soil surface (e.g. rosette plants) or prostrate growth forms
2)	long basal	leaves > 0.5m long, emerging from soil surface but not forming tussocks
3)	semi basal	significant leaf area deployed both close to soil surface and higher up the plant
4)	erect leafy	essentially erect, leaves concentrated in middle or top parts
5)	cushions (= pulvinate)	tightly packed foliage close to soil surface with relatively even and rounded canopy boundary
6)	tussocks	many leaves from basal meristems forming prominent tufts
7)	dwarf shrubs	woody plants up to 0.8m tall
8)	shrubs	woody plants with main canopy deployed relatively close to soil surface on one or more relatively short trunks
9)	trees	woody plants with main canopy elevated on one substantial trunk
10)	leafless shrubs or trees	with green, non-succulent stems as main photosynthetic structure
11)	short succulents	plant height < 0.5m, green globular or prostrate “stems” with minor or no leaves
12)	tall succulents	plant height >0.5m, green column “stems” with minor of no leaves
13)	palmoids	with a rosette of leaves on the top of a stem
14)	epiphytes	growing on trunk or in canopy of shrubs or trees
15)	climbers/ scramblers	root in soil and use external support for growth and leaf positioning
16)	hemi-epiphytes	germinate in other plants and establish roots in ground or plants that germinate on the ground, grow up trees and disconnect soil contact
17)	hemi-/holoparasites	haustoria tapping into branches of shrubs or trees to support green foliage
18)	aquatic submerged	all leaves submerged in water
19)	aquatic floating	most leaves floating on water
20)	other growth forms	brief description to be given

2.8.6. Clonality

Adult plants persist by acquiring space through vegetative production (Weiher et al., 1999). Clonality is ability of a plant species to reproduce vegetatively, to produce new ramets and to expand horizontally (Cornelissen, et al., 2003b). Colonality can give plants competitive vigour and ability to exploit patches rich in key resources like nutrients and water. It may also promote persistence after environmental disturbances [like grazing]. Clonal organs, especially below ground ones, may also serve as storage organs (Cornelissen et al., 2003b).

Clonality, and capacity to spread laterally, are difficult to measure. An impediment is time and effort, to excavate and carefully follow rhizomes through the soil. A simple binary trait is what can easily be measured: clonal or non-clonal (Weiher et al., 1999). Cornelissen et al (2003b) propose more distinct categories (Table 7). More detailed, qualitative groupings have been suggested like four basic forms of plant clonality (+/- splitting, combined with +/- spreading) which are subdividd into 16 general forms (van Groenendahl et al., 1997 in Weiher et al., 1999). A global study has shown, that grazing increases the abundance of stoloniferous and rosette plants (Diaz et al., 2007).

Table 7. Categories of clonality (Cornelissen et al., 2003b)

1	non-clonal
2	clonal aboveground: - stolons: horizontal stems - gemiparous: adventitious buds on leaves - other vegetative buds or plant fragments clonal belowground: - rhizomes: more or less horizontal belowground stems - tubers: modified belowground stems or rhizomes often functioning as storage organs. Tubers are shaped short, thick and irregularly rounded, often covered with modified buds but not by leaves or scales - bulbs: short, more or less globose belowground stems covered by fleshy, overlapping leaves or scales, often serving as storage organs - adventitious root buds on main roots

2.8.7. Spinescence

A spine is usually a pointed, modified leaf, leaf part or stipule. A thorn is a hard, pointy, modified twig or branch. A prickle consists of modified epidermis. All three types play an obvious role in anti-herbivore defence. Additionally they may play additional roles in reducing heat or drought stress and spiny plants may provide other plant species with refuge from herbivores. (McIntyre et al., 1999, Cornelissen et al., 2003b). For measuring spinescence Cornelissen et al (2003b) propose to treat it as categorcial trait and summarise spines, thorns and prickles under the term “spine equivalent” (Table 8).

Table 8. Spine equivalent categories

0	no spines, thorns or prickles
1	low or very local density of soft spine equivalents < 5mm; plant may sting or prickle a little, when hit carelessly
2	High density of soft spine equivalents, intermediate density of spine equivalents of intermediate hardness or low density of spine equivalents of hard, sharp spine equivalents > 5mm; plant hurts when hit carelessly
3	Intermediate or high density of hard, sharp spine equivalents > 5mm; plant hurts a lot when hit carelessly
4	Intermediate or high density of hard, sharp spine equivalents > 20mm; plant may cause significant wounds when hit carelessly
5	Intermediate or high density of hard, sharp spine equivalents > 100mm; plant is dangerous to careless large mammals including humans

2.9. Trait transect

This method focuses on biological traits of plant communities. It is used to determine aggregated values and range of variation of functional traits in an herbaceous community without prior knowledge of floristic composition (Gaucherand & Lavorel, 2007).

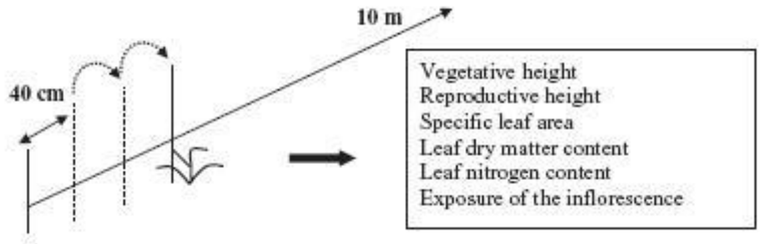

Fig. 14 trait transect and measured traits (Gaucherand & Lavorel, 2007)

Adapted from a linear vegetation point transect it consists of 25 points on a 10m long line (Gaucherand & Lavorel, 2007). A stick is planted vertically every 40cm following 10m line across sample site (Fig. 14). Traits are measured on every individual in physical contact with a stick. Species identity does not matter. Only very young and very damaged plants are not measured (Gaucherand & Lavorel, 2007). To find appropriate sites for tansects is left to judgement and experience of the researcher (Cornelissen et al., 2003b).

3. Material and Methods

This chapter gives an overview about research area, research partners, data collection and data analysis.

3.1. Study area

Field work was undertaken from 16 March 2008 to 16 June 2008. The study area is situated in south-western Uganda. Field work was carried around Mbarara and Rushere, Kiruhura and Mbarara districts. Laboratory work took place at the Department of Animal Science at Makerere University, Kampala. Mbarara is located at a latitude of 0° 39' 30S, a longitude of 30° 40' 33E and an altitude of 1436m above sea level (Fallingrain.com, 2008). Rushere is located at a latitude of 0° 14' 12S, a longitude of 30° 57' 40E and an altitude of 1375m above sea level (Fallingrain.com, 2008).

The study area is situated on the upwarped Tanganyika surface. A landscape with undulating plains in some and sloping to moderate steep topography in other areas. Soils are deep, reddish-brown sandy loams or sandy clay loams overlying plinthite. Large areas are grassland, used as rangeland. Around Mbarara soils are generally acid, well leached and of low fertility. Around Rushere soils are yellowish-red, sandy clay loams underlain by plinthite, acid and highly leached. (Aniku, 2001). The agro-ecological zone is defined as pastoral system zone (Komutunga & Musiitwa, 2001). More precisely south-western pastoral system zone (Parsons, 1970). A different source, focusing on livestock production, defines two agro-ecological zones in the area: western banana-coffee-cattle system and pastoral and some annual crops system (Mugerwa, 2001). Rainy season starts beginning of March and ends end of May. Natural vegetation is dry *Acacia* woodland (Aluma, 2001), also called dry *Acacia* Savanna in earlier literature (Langdale-Brown, 1970). It is typified by a light to moderate cover of feathery-leaved, thorny *Acacia* trees. Dominant species are *Acacia gerrardii* (*Grey haired acacia*) and *Acacia hockii* where rainfall ranges from 740 mm - 1140 mm per annum with well marked dry seasons. Grass layer is dominated by two different communities: *Themeda triandra* and *Cymbopogon afronadus*. *Cymbopogon* communities are more common in areas with higher rainfall, *Themeda* communities are more abundant in dry areas and dry situations like hill-slopes and shallow hill-top soils (Aluma, 2001).

The Bahima people, traditional cattle keepers, inhabit the area. They used to be nomadic and totally dependent on cattle, bartering livestock products for food crops from neighbouring peoples (Musiitwa & Komutunga, 2001). As Parsons wrote, 38 years ago: “The pastoral Bahima of Ankole undertake no agriculture whatsoever but practice a purely nomadic pastoral existence” (Parsons, 1970). Since the 1970s the government of Uganda has attempted to settle the Bahima by creating blocks of land within grazing areas and providing water through building dams, dips and water holes (Musiitwa & Komutunga, 2001). Pasture in this part of Uganda is estimated to produce mean annual dry matter of 3900 kg/ha with a mean estimated carrying capacity of 1.63 LU/ha (Mugerwa, 2001). A different source measured a mean annual dry matter yield of 2292 kg/ha in the study region. During long rainy season mean dry matter yield reaches 3045 kg/ha (Kagoda 2001).

3.2. Data collection

Data collected can be divided into three subgroups. The 1st subgroup contains samples for pasture analysis: plant traits, pasture productivity, plant identification. The 2nd subgroup contains information from interviewees (furthermore called “farmers”): pasture management, pasture quantity, pasture quality, erosion, pasture vegetation. The 3rd subgroup contains data from chemical analysis of pasture samples.

3.2.1. Farm selection

Farms selected keep crossbred and Ankole cattle on different pastures. 2 pastures were selected on each farm. One grazed by crossbred cattle and the other grazed by Ankole cattle. Farmers were asked if they had a paddock or grazing area not stocked during time of assessment. In most cases, cattle was permanently kept on the same pasture.

Fig. 15 Project farms selected for this study

Specific sampling sites were chosen randomly to be as representative as possible by walking across chosen paddocks. It was tried to exclude frequently disturbed sites like surroundings of stock watering points or cattle handling facilities.

3.2.2. Time of data collection

Data collection was carried out in two separate rounds (also called “transect rounds” further on) divided by approximately four weeks. Intention of splitting data collection was, a comparison of certain parameters across time. In both data collection rounds, the same protocol was followed. The first transect round took place from 22. March 2008 to 9. April 2008, with a break from 23. March to 31. March. Second transect round took place from 7. May 2008 to 23. May 2008.

3.3. Survey of pasture management and vegetation

Two questionnaires were developed and used to interview farmers. Answers given were recorded on questionnaires and later inserted into an Excel sheets for further analyses.

3.3.1. Survey of pasture management

This questionnaire was developed before field work (chapter 9.2). It contained questions about pasture yield, pasture quality, pasture management and erosion. Interviews were conducted in the local language and translated to English by the interviewer (Fig. 16).

Overall performance of pastures was assessed by asking farmers to estimate the percentage of low, medium and high yielding pasture which was supposed to add up to a total of 100%. This categories could not be explained easily and usually some time was needed to explain their meaning. Questions about pasture quality were similar. For each paddock chosen for pasture analysis, specific questions were asked. Questions dealt with paddock size, reasons for suitability for herd type grazing the paddock, pasture quality, erosion and pasture management.

3.3.2. Survey of pasture vegetation

This questionnaire (chapter 9.3) was developed between data collection rounds. Questions focused on pasture vegetation trying to find out, if there were difference between pastures stocked with different herd types.

Fig. 16 Dr. Asiimwe conducting an interview

Fig. 17 Herdsmen interested in sampling procedure

3.4. Pasture analysis

Pastures on 10 dairy farms have been analysed using several methodological tools.

3.4.1. Trait transects

Methodology described in Gaucherand & Lavorel (2007, chapter 0) was slightly adjusted. Trait transects were performed only during first data collection round. A repetition was not considered necessary. Pasture plant traits were not expected to change significantly between data collection rounds. Transect poles were sized approximately 2cm x 4cm x 80cm, made of wood and painted white at the top. This eased identification of sampling sites during for the second round of data collection, as one pole per site was left behind. 1 pole was planted every meter (Fig. 20). Poles were forced into the ground using a hammer. String was used to indicate a transect line (Fig. 18, Fig. 19). It was cut at correct length (10m) and used for all transects. Intervals of 1m were marked on the string with isolation tape to fix measuring points. 40 trait transects were performed on 20 pastures of 10 farms. 2 transects were performed on every pasture resulting in 4 transects per farm.

Fig. 18 Trait transect (farm 5, Ankole 1)

Fig. 19 Trait transect (farm 4,crossbred 1)

Every plant touching a post was cut (Fig. 21). Plants were cut with a paper cutter or a Swiss army knife. Analysis concentrated on herbaceous understory plants, defined (according to Landsberg et al., 1999) as those with the bulk of foliage within 50cm off ground. On the first day, plants were measured immediately after having been cut. Due to harsh climatic conditions the procedure was adapted. Instead of measuring plants on the spot they were put into small plastic bags and closed air tight immediately after cutting to keep best possible condition, until measurements took place (Fig. 22, Fig. 23). Deep freezer plastic bags were used. Plants were measured with a ruler (Fig. 24).

Fig. 20 Transect post (farm 4, crossbred 2)

Fig. 21 Measuring point (farm 8, crossbred 2)

Plant traits collected were: plant height in cm, reproductive height in cm, leaf width in mm, leaf length in mm, life form (grass, legume or herb), growth form (20 possible categories), above ground clonality (classes 0-3) and spinescence (classes 0-5).

Plant measurements took place, during the afternoon of collection day or, at latest, during the following day. Measurements followed Cornelissen et al. (2003b). Very long plants were measured in the field (Fig. 25) and only parts taken for later measurement of leaf traits. Measures were noted on transect data sheets.

Fig. 22 Plants in plastic bag (farm 3, crossbred 2)

Fig. 23 One bag per post (farm 4, crossbred 1)

Classification of growth form, spinescence and clonality was done by field observation (Gaucherand & Lavorel, 2007). The term life form in this work is understood as in Landsberg et al (1999). Time needed per trait transect was highly variable and dependent upon local conditions (sward height, plant density and accessibility of site). Time needed ranged from 45 minutes to 90 minutes. Plant measuring could take up to 3 hours for 1 farm. On each site personal impressions were recorded. Approximate position of transect lines, in reference to easily identifiable objects (for instance termite mounds, fences, gates,..) was recorded to ease identification during second data collection round. Photos were taken at each site. The camera used was a Pentax Optio S10 10Mpixel.

Fig. 24 Measuring traits (farm 1, crossbred 1)

Fig. 25 Measurement of long plants (farm 1, crossbred 1)

3.4.2. Pasture productivity

Pasture productivity was sampled during both data collection rounds. Poles, marking sites, sometimes could not be retrieved or had been removed. Using memory, notes in the research diary and, where available, advice from local guides (herdsmen, farmers) it was tried to come as close as possible to original sampling sites.

Above ground biomass of 2 sample plots (0.2m x 5m = 1m²), close to each trait transect site, was collected. Sampling sites were chosen according to visual similarity with respective trait transect sites. On most farms samples were taken approximately parallel to the transect line during the first and perpendicular to the transect line during the second round of data collection. 2 samples were taken from both sides of respective transect lines. Distances of sampling sites from transect lines varied.

The sampling area was marked with four transect posts and string indicating boundary lines (Fig. 26). A machete, a standard local product, was used to sever overlapping biomass (Fig. 27). Sampling was done with an accu-powered grass cutting device (Fig. 28, Fig. 29). The grass cutting device was an accu edging shear made by GARDENA (model accu 100 article number 8805). On the last pasture sampled (Ankole pasture, farm 10) the cutting device could not be used so samples were taken manually. Samples of 2 pastures (crossbred pasture farm 10 and crossbred pasture farm 9) had to be collected while wet.

Biomass was gathered using a small rake and put into plastic bags, closed as airtight as possible and labelled accordingly. Fresh matter of was determined as soon as possible after sampling. Weights were determined with a weighing scale made by Seco Digital Weigh Scales, Kampala. Maximum scale capacity was 10kg, minimum weight, possible to determine 1g. Weights of pasture and pooled samples were recorded in pasture productivity data sheets. After weighing samples were pooled according to transect site. From pooled samples approximately 0.5kg were taken, weighed again, labelled and taken for further analysis to Makarere University, Kampala. Until samples could be taken to Makerere University they were stored open to avoid molding and rotting.

Fig. 26 Pasture productivity sampling (farm 1, crossbred 1)

Fig. 27 Severing overlapping plants (farm 1, crossbred 1)

Fig. 28 Electric cutting device 1 (farm 1, crossbred 1)

Fig. 29 Electric cutting device (farm 1, crossbred 1)

3.4.3. Plant identification

At sampling sites dominant, herbaceous plant species were collected and bagged until identification. Later they were shown to qualified persons available (either farmer or herdsman, in one case the farmers´ wife also took part). Information asked for were local name, if the plant was considered to be "good" or "bad" and special plant qualities (chapter 9.5). Data was noted on plant identification sheets. Correct spelling, English names and botanical names were identified by Dr. D. Mpairwe of Department of Animal Science at Makerere University. Data on plant identification could not be collected from all farms. From questionnaires and from observation during field work it can be assumed, that dominant species on assessed pastures were fairly homogenous.

3.5. Laboratory work

Laboratory work was carried out at the Animal Science Laboratory of the Department of Animal Science at Makerere University, Kampala. Samples for all analyses were weighed using a digital weighing scale made by Denver Instrument Company (model AA-200). Data acquired during laboratory analyses was recorded in a research diary. All data was entered into Excel sheets for statistical analyses. Results from analyses made by technicians after field work were communicated by email and on receiving entered into Excel sheets as well.

3.5.1. Preparation of pasture samples

Pasture samples were dried in an UNITHERM Drier (Birmingham and Blackburn Construction Co. Ltd) and a second drier made by LEEC at 60°C to constant weight. Dry matter was recorded on pasture productivity data sheets. Dry matter was determined to an accuracy of 1g. By accident one sample bag had remained closed after collection which led to rotting. Samples were ground to a size of 1mm at Makerere University Agricultural Research Institute (MUARIK) in Kabanyolo. Ground samples were stored in sealable plastic bags. 1 sample was lost during transport to MUARIK. 2 samples were returned carrying the same label. Ground samples were labelled consecutively according to usual conduct of the laboratory.

Fig. 30 Pasture sample before grinding

Fig. 31 Pasture sample after grinding

3.5.2. Digestion

Between 0.2g and 0.3g of ground sample were transferred into a digestion tube. Mixed digestion catalyst and 10ml concentrated sulphuric acid (H_2SO_4) were added. The mixture was digested at 320°C until clear. For digestion a Kjeldahterm made by GERHARDT was used (Fig. 32). After digestion distilled, deionised water was added to prevent samples from evaporation.

Fig. 32 Digestion of pasture samples

Fig. 33 Dilution of digested samples

3.5.3. Dilution

Digested samples were transferred into volumetric flasks and filled up with distilled, deionised water to 100ml (Fig. 33). Between dilution of different samples all equipment was thoroughly rinsed. In storage containers diluted samples were labelled correctly.

3.5.4. Gross energy content determination

The analysis of gross energy content was done by technicians of the laboratory. It was decided to test 8 samples taken on 1 farm. To determine differences in gross energy content over time all samples collected on 1 farm during both data collection periods were analysed. Energy contents were expected to be quite homogenous across study area. Gross energy determination was done using determination of gross energy by Parr Adiabatic Oxygen using a bomb calorimeter (made by GALLENKAMP model: Autobomb Cat No CAB 001 ABI. C, made in UK).

Gross energy is defined as the heat released, when carbon and hydrogen present in a substance are completely oxidized to carbon dioxide and water. It is synonymous with heat of combustion burning a sample of the substance in a bomb calorimeter (Fuller, 2004).

3.5.5. Crude protein determination

Kjeldahl´s method was used to determine crude protein content of pasture samples. A semi-automatic appliance was used for sample distillation. (2200 KJELTECH Auto Distillation Foss Tecator) (Fig. 34). Titration was done using a JENCONS Digitrate with a capacity of 50ml. To calculate crude protein content in percent following formula was used:

$$\text{crude protein in \%} = \frac{6.2 * 14 * \text{titre in ml} * \text{molarity of acid} * 100 * \text{dilution factor}}{\text{sampleweight in g} * 1000}$$

79 samples were analysed. Every sample was tested once as there were two samples per pasture collected representing a double determination of crude protein content for every pasture.

Fig. 34 2200 KJELTECH Auto Distillation Foss Tecator

Fig. 35 Foss Fibertech 2010

3.5.6. Neutral detergent fibre (NDF) determination

79 samples were analysed.The appliance used to determine neutral detergent fibre (NDF) broke down during the first run and could not be repaired in time to finish analyses. The analysis was later carried out by technicians of the laboratory. Neutral detergent fibre was

determined using the neutral detergent method for cell-wall constituents. The appliance used was a Foss Fibertech^{tm} 2010 (Fig. 35). Neutral detergent fibre mixture used for analysis consisted of 30g sodiumlaurylsulphate, 18.61g ethylenediaminetetraacetate (EDTA), 6.81g sodiumboratedecahydrate, 4.56g disodiumhydrogenphosphate and distilled, deionised water.

$$\text{Neutral detergent fibre in \%} = \frac{\text{absorbance} * 100 * \text{final volume in ml}}{\text{gradient} * 1000 * 5 * \text{sampleweight in g}}$$

Every sample was tested once as there were two samples per pasture collected representing a double determination of neutral detergent fibre content for every pasture.

3.5.7. Phosphorus determination

Phosphorus content was analysed using spectrophotometry. The spectrophotometer used was a JENWAY 6405 UV/Vis. spectrophotometer. Phosphorus was determined using a wavelength of 400nm measuring sample absorbance. Phosphorus stock solution needed was mixed by dissolving 8.788g of potassiumdihydrogen phosphate (KH_2PO_4) in distilled water and filling the solution up to 1l. For phosphorus working solution 50ml of phosphorus stock solution were diluted in 1 litre of distilled, deionised water. For calculation a standard calibration curve was needed. The gradient needed could be calculated using following formula:

$$\text{Concentration} = \frac{\text{absorbance}}{\text{gradient}}$$

To calculate phosphorus content in percent following formula was used:

$$\text{Phosphorus content in \%} = \frac{\text{absorbance} * 100 * \text{final volume in ml}}{\text{gradient} * 1000 * 5 * \text{sampleweight in g}}$$

79 samples were analysed. Every sample was tested once as there were two samples per pasture collected representing a double determination of phosphorus content for every pasture.

3.5.8. Calcium determination

Calcium analysis could not be carried out during field work. It was carried out by technicians of the laboratory. Calcium was analysed using flame photometry. A JENWAY Flame Photometer with a factory fitted calcium filter (model PFP7 Serial no. 10256) was used to determine emission of calcium. A standard calibration curve was calculated and a gradient determined. Concentration was calculated using following formula:

$$\text{Concentration} = \frac{\text{gradient}}{\text{optical density}}$$

Following formula was used to calculate calcium content in %:

$$\text{Calcium in \%} = \frac{100 * \text{dilution factor} * 100 * \text{concentration}}{\text{sampleweight converted to ppm}}$$

78 samples were analysed. Every sample was tested once as there were two samples per pasture collected representing a double determination of calcium content for every pasture.

3.6. Data analysis

Data sets were analysed using different methods. Where applicable minima, maxima, mean and median values were calculated from SAS output and questionnaires using Excel. Excel was also used for drawing graphs.

3.6.1. Analyses of pasture management and vegetation

Questionnaires were analysed manually. Due to the small number (20) it was not considered necessary to use a computer program for statistical data analysis. Where possible percentages or frequencies, minima, maxima, mean and median values were calculated with Excel. Graphs were also drawn using Excel.

3.6.2. Analyses of trait transects

Data was divided into continuous and discontinuous traits for statistical analysis. Continuous traits are plant height in cm, reproductive height in cm, leaf width in mm and leaf length in mm. Discontinuous traits are life form, growth form, clonality and spinescence.

Continuous traits were analysed using general linear model in SAS 9.1 (Copyright 2002-2003 by SAS Institute Inc., Cary, NC, US):

$y = \mu + F_i + B_j + (FB)_{ij} + \varepsilon_{ij}$

μ = mean

F= fixed effect farm with factor levels i = 1,2,3,…,10

B = fixed effect breed with factor levels j = a (Ankole), c (crossbred)

FB = effect on interaction between farm and breed

ε = residuals

Discontinuous traits were analysed using procedure frequency in SAS 9.1 (Copyright 2002-2003 by SAS Institute Inc., Cary, NC, US). To enable analysis separated by breed procedure sort was used to sort by breed.

3.6.3. Analyses of pasture productivity

Fresh and dry matter yields were analysed using general linear model in SAS 9.1 (Copyright 2002-2003 by SAS Institute Inc., Cary, NC, US):

$y = \mu + F_i + B_j + S_k + (FB)_{ij} + (FS)_{ik} + (BS)_{jk} + \varepsilon_{ijk}$

μ = mean

F = fixed effect farm with factor levels i = 1,2,3,…,10

B = fixed effect breed with factor levels j = a (Ankole), c (crossbred)

S = fixed effect season with factor levels k = 1 (late dry season), 2 (early wet season)

FB = effect of interaction between farm and breed

FS = effect of interaction between farm and season

BS = effect of interaction between breed and season

ε = Residuals

Dry matter percent was analysed using the same statistical procedure and model: The formula used for calculation of moisture in percent was:

$$\text{moisture in \%} = \frac{\text{weightloss after drying} * 100}{\text{fresh sampleweight}}$$

Resulting percentages were deducted from 100 to determine dry matter percent. 4 samples had to be harvested wet leading to fresh matter being incorrect at weighing. 1 sample happened to rot before determination of dry matter. These samples were not used for statistical analysis. 75 samples were used for statistical analysis of fresh matter, dry matter and dry matter content.

3.6.4. Analyses of nutrients

For analyses of crude protein content, neutral detergent fibre content, phosphorus content and calcium content general linear model in SAS 9.1 (Copyright 2002-2003 by SAS Institute Inc., Cary, NC, US) was used. 76 samples could be used for statistical analysis:

$y = \mu + F_i + B_j + S_k + (FB)_{ij} + (FS)_{ik} + \varepsilon_{ijk}$

μ = mean

F = fixed effect farm with factor levels i = 1,2,3,…,10

B = fixed effect breed with factor levels j = a (Ankole), c (crossbred)

S = fixed effect season with factor levels k = 1 (late dry season), 2 (early wet season)

FB = effect of interaction between farm and breed

FS = effect of interaction between farm and season

ε = Residuals

For gross energy content a different model had to be used as the 8 samples tested originated from 1 farm only. General linear model in SAS 9.1 (Copyright 2002-2003 by SAS Institute Inc., Cary, NC, US) was used.

$y = \mu + B_i + S_j + (BS)_{ij} + \varepsilon_{ijk}$

μ = mean

B = fixed effect breed with factor levels i = a (Ankole), c (crossbred)

S = fixed effect season with factor levels j = 1 (late dry season), 2 (early wet season)

BS = effect of interaction between breed and season

ε = Residuals

4. Results

Results are presented separated according to data sets. For different parameters LSMEANS were calculated. Following terms are used for identification of different means:

- Farm mean = LSMEANS calculated per farm.
- Breed mean = LSMEANS calculated per breed (meaning different herd type and respective management on a certain pasture, not pure breed effect).
- Season mean = LSMEANS calculated per season.
- Pasture mean = LSMEANS calculated for the effects of an interaction between farm and breed. Therefore LSMEANS calculated by pasture.
- Seasonal breed mean = LSMEANS calculated for the effect of an interaction between season and breed.
- Seasonal farm mean = LSMEANS calculated for the effect of an interaction between season and farm.

4.1. Results of the survey of pasture management

The questionnaire on pasture management has been filled out on all farms (10).

4.1.1. Number of paddocks

Nine farmers provided information on number of paddocks on their farms. Numbers given vary from 1 to 10 paddocks. Most farms did not possess what was understood as paddock prior to field work namely a number of small grazing areas separated by fences. Most farms (3 out of 10) had 1 paddock followed by 2 farms with 2 paddocks. Therefore 55% of farms had 1 or 2 paddocks. 4 farms had more than 2 paddocks (3, 6, 9 and 10 paddocks represented by 1 farm respectively).

4.1.2. Paddock size

Farmers were asked to estimate sizes of pastures where samples have been taken (Table 9, Fig. 36).

Table 9. Estimated pasture size according to breed

	pasture sizes in ha		
farm	crossbred	Ankole	all
1	100.00	61.00	161.00
2	120.00	65.00	185.00
3	15.00	100.00	115.00
4	51.00	61.00	112.00
5	5.00	100.00	105.00
6	9.00	120.00	129.00
8	65.00	50.00	115.00
9	4.00	51.00	55.00
10	12.00	108.00	120.00
mean	42.34	79.49	121.83
median	15.00	65.00	115.00
minimum	4.00	50.00	55.04
maximum	120.00	120.00	185.00

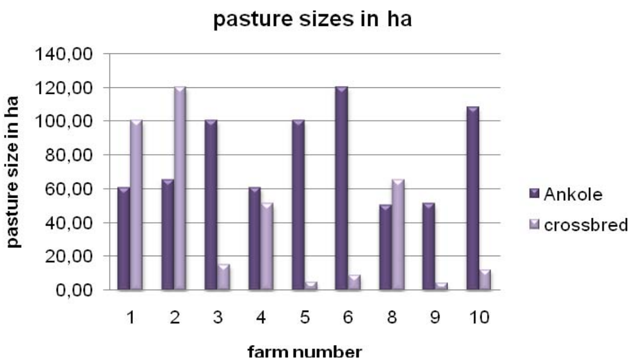

Fig. 36 Pasture sizes in ha

Size of pastures analysed per farm ranged from approximately 55ha to 185 ha (mean: approximately 122ha, median: 115ha). Estimated single paddock size ranged between 4ha and 120ha (mean 60.91ha, median 60.69ha). Estimated mean/median size of pastures stocked with crossbred cattle (mean: approx. 42 ha, median: 15 ha) was smaller than estimated mean/median size of Ankole pastures (mean: approx. 79ha; median: 65ha). On 6 farms, Ankole pastures were larger, on 3 farms crossbred pastures were larger. The difference between Ankole and crossbred pasture size was especially high on 5 farms (farms 3,5,6,9 and 10). On all these farms Ankole pastures were a lot bigger than crossbred pastures. The difference in pasture size between pastures stocked with different breeds was not as significant on the other 4 farms. On three of them crossbred pastures were bigger than Ankole pastures (farms 1, 2 and 8).

4.1.3. Pasture yield

Farmers estimated percentages of low, medium and high yielding pasture on their respective farms. 3 farmers differentiated between low and high yielding, 3 between medium and high yielding, 2 divided their pasture into all three categories. 1 differentiated between low and medium yielding pasture (Table 10, Fig. 37).

7 out of 10 farms have low yielding pastures. 7 out of 10 farms have medium yielding pastures. 8 out of 10 farms have high yielding pastures (Table 10). Most pasture was estimated to be high yielding, followed by similar percentages of medium and low yielding pasture.

Low yielding pasture range between 0% and 66% (lowest: farm 3 (5%); highest: farm 1 (66%) median: 18%). Medium yielding pasture range between 0% and 65% (lowest: farm 8, farm 19 (10%); highest: farm 9 (65%); median: 15%). High yielding pasture range between 0% and 95% (lowest: farm 1 (33%); highest: farm 10 (90%); median: 65%).

Table 10. Estimated pasture yield per farm in %

	pasture yield in %		
farm	**low**	**medium**	**high**
1	66	0	33
2	10	0	90
3	5	0	95
4	0	20	80
5	25	35	40
6	60	40	0
7	30	20	50
8	0	10	90
9	35	65	0
10	0	10	90
mean	23	20	57
median	18	15	65
minimum	0	0	0
maximum	66	65	95

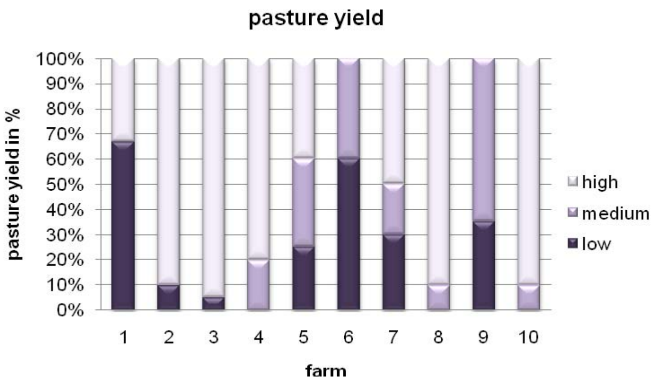

Fig. 37 Estimated pasture yield per farm in %

Farmers were also asked to estimate yield of those pastures, samples were taken from (Table 11, Fig. 38).

Overall most pastures were estimated to be medium yielding (11), followed by 6 high yielding and 3 low yielding pastures. Separated by herd results differ. Crossbred pastures were estimated to be either high or medium yielding (5 high, 5 medium). Ankole pastures were estimated to be rather medium (6) or low (3) yielding.

Table 11. Estimated pasture yield per breed

	pasture yield (n=20)		
breed	**low**	**medium**	**high**
crossbred	0	5	5
Ankole	3	6	1

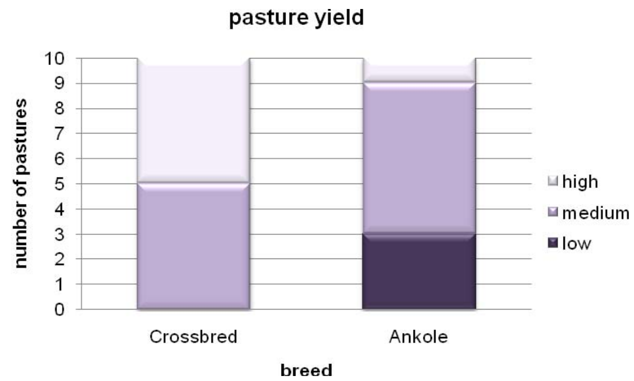

Fig. 38 Pasture yield per breed

4.1.4. Pasture quality

Farmers estimated pasture quality. They estimated percentages of low, medium and high quality pasture. 3 farmers separated between medium and low quality. 3 farmers between medium and high quality. 2 farmers between low and medium quality. 2 farmers separated their pastures between all three quality categories (Table 12, Fig. 39).

Most pasture was estimated to be of high quality (8) followed by medium quality (7) and low quality pastures (7). Percentages of low quality pasture range from 0% to 50% (from 10% (farm 2 and 3) to 50% (farm 1 and 6); median: 12.5%). Percentages of medium quality pasture range from 0% to 65% (from 10% (farm 8 and 10) to 65% (farm 9); median: 15%). Percentages of high quality pasture range from 0% to 90% (from 20% (farm 7) to 90% (farms 2, 8 and 10); median: 75%).

Table 12. Estimated pasture quality per farm in %

	pasture quality in %		
farm	**low**	**medium**	**high**
1	50	0	50
2	10	0	90
3	15	0	85
4	0	20	80
5	10	20	70
6	50	50	0
7	20	60	20
8	0	10	90
9	35	65	0
10	0	10	90
median	12.5	15	75
mean	19	23.5	57.5
minimum	0	0	0
maximum	50	65	90

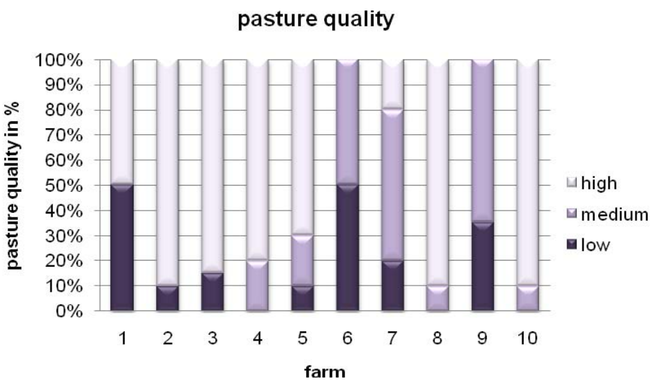

Fig. 39 Pasture quality per farm in %

Farmers were asked to estimate pasture quality of pastures samples were taken from (Table 13, Fig. 40). Most pastures analysed were of medium quality (11) followed high quality (6) and low quality (3).

Crossbred cattle were kept on medium (5) or high (5) quality pastures. No crossbred pasture was estimated to be of low quality. Ankole cattle was mostly kept on medium quality pastures (6) followed by low quality (3) and high quality (1). From personal impression, gathered during sample collection, estimation given can be supported. During sample collection it was perceived that overall Ankole herds seemed to be kept on poorer pastures than crossbred herds.

Table 13. Estimated pasture quality per breed

	pasture quallity (n=20)		
breed	**low**	**medium**	**high**
crossbred	0	5	5
Ankole	3	6	1

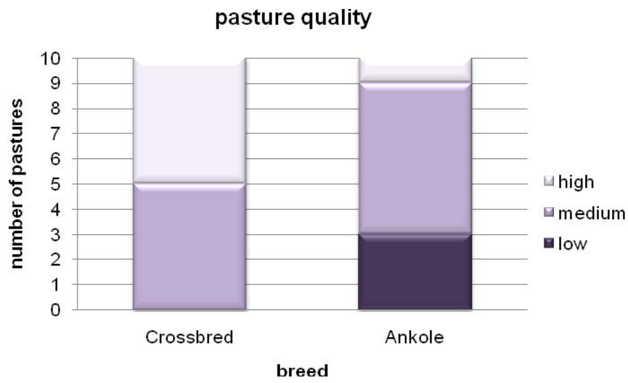

Fig. 40 Estimated pasture quality per breed

4.1.5. Pasture management

Farmers were asked if they would keep only the indicated herd (either Ankole or crossbred) on a selected pasture. Facilities needed for herd management (like crushes for different management tasks, milking areas, dips/spraying areas for parasite treatment,..) were excluded from this separation.

With one exception only farmers reported they would keep exclusively 1 herd type on a selected pastures. For 1 pasture no answer was recorded. On most paddocks (16 or 80%) cattle was permanently present. Ankole cattle was more likely to be kept permanently on the same pasture (90% of Ankole, 70% of crossbred pastures). One farm stocks their crossbred pastures at intervals of 9 weeks. This farm was a special case as it had 9 fenced paddocks for their crossbred herd and kept rotating among these paddocks. After approximately nine weeks one rotation was finished. This farm was also the only one which practised some form of fodder conservation, by cutting hay, which could be observed during one of the visits.

Table 14. Qualities making pastures suitable for dedicated herd type

Pasture especially suitable because..	**crossbred pastures with this quality** (n=10)	**Ankole pastures with this quality** (n=10)
water readily available	2	0
water not readily available	0	3
pasture improved	1	0
pasture not improved	0	1
high quality feed	7	1
minor quality feed	0	5
area cleared	7	0
area not cleared	0	5
close to house	3	0
further away from house	0	1
no weeds	1	0
animals not kept for dairy production	0	1

Every pasture was especially suitable for its dedicated herd type. Different reasons were given (Table 14). Most frequently mentioned reasons for suitability for crossbred cattle were availability of high quality feed (70%), practise of bush clearing (70%) and closeness to the house (30%) (important due to more intensive herd management of crossbred cattle). Most frequent reasons mentioned for suitability for Ankole cattle were that no bush clearing had taken place (50%), availiability of only minor quality feed (50%) and unavailability of water (30%).

Some form of pasture improvement) was done on all pastures but 1 (the exception being an Ankole pasture). Farmers were asked to name improvement methods. Bush clearing was practised on all pastures undergoing improvement. Additionally unpalatable plants, like lemongrass (*Cymbopogon afronardus*), were being removed from 1 crossbred pasture.

4.1.6. Erosion

Of 20 pastures assessed, 4 were described as being affected by erosion. According to farmers no crossbred pastures were affected by erosion. 40% of Ankole pastures were described as being affected by erosion. Farmers have to deal with erosion caused by water. The extent of erosion was neither increasing nor decreasing.

4.2. Results of the survey of pasture vegetation

The second questionnaire was filled out on all farms.

4.2.1. Changes in pasture composition

Seven out of 10 of farmers acknowledged, that certain plants have disappeared from their pastures during the last 10 years. 3 farmers did not notice disappearance of any plants.

When asked to name plants that have disappeared, farmers named (in brackets: botanical name; number of times mentioned): “Embuarara” (*Hyparrhenia rufa;* 5), “Orunyankokole” (*Chloris gayana;* 2) and “Ekijubwe” (*Brachiaria sp.;* 1).

Seven farmers stated new plants have been noticed during the last 10 years. New plants mentioned were: “Egashi” (*Sporobolus pyramidalis;* 4), “Ekihuki” (*Lantana camara;* 3), “Omutete” (*Cymbopogon afronardus;* 1) and “Marende” (*n.s.;* 1). 3 farmers answered, there were no new plants known to them

4.2.2. Common pasture plants

Farmers were asked for pasture plants they considered to be “good”.

Good plants were defined as being beneficial for animal welfare, animal production, pasture productivity or pasture quality (Table 15). 9 plants were mentioned by farmers. Plants mentioned most frequently were “Emburara” (*Hyparrhenia rufa;* 80%), “Ekijubwe” (*Brachiaria sp.;* 80%) and “Eyojwa” (*Themeda triandra;* 40%).

12 different qualities were ascribed to “good” plants. Some farmers did not specify any qualities, just named plants. As “good” qualities nutritive value (17), being able to increase production (6) and drought resistance (5) were most frequently named. Interestingly 1 farmer described “Eyojwa” (*Themeda triandra)* as not being drought resistant while 2 other farmers, described it as being drought resistant.

Table 15. Plants considered “good” and their qualities

plant (times mentioned)		
local name	**botanical name**	**qualities described (times mentioned)**
Emburara (8)	*Hyparrhenia rufa*	highly nutritious (6) increases milk production (2) drought resistant (3) cows produce concentrated milk (1) fattens animals (1) palatable (1)
Ekijubwe (8)	*Brachiaria sp.*	highly nutritious (6) increases milk production (2) animals grow fat and are healthy (1) soft (1) plants have herbage (1) very palatable (1) not drought resistant (1)
Orunyankokole (3)	*Chloris gayana*	highly nutritious (1) nitrogen source (1) fattens animals (1) increases milk production (1) rare plant (1)
Kyooya (1)	*n.s.*	soft plant (1)
Ekikamba (1)	*n.s.*	nitrogen source (1)
Marende (1)	*n.s.*	nutritious (1)
Eyojwa (4)	*Themeda triandra*	nutritious (3) drought resistant (2) not drought resistant (1) sprouts very fast after rain (1)
Orukwamba (1)	*Cynodon sp.*	
Eyojo (1)	*n.s.*	animals like it especially at rest (1) animals fatten (1) increases milk production (1)

Farmers were asked to name three pasture plants they considered as “bad”. This meant plants with negative effects on animal welfare, animal production, pasture productivity or pasture quality (Table 16). Some farmers did not specify any qualities.

Table 16. Plants considered “bad” and their qualities

plant (times mentioned)		
local name	**botanical name**	**qualities described (times mentioned)**
Egashi (10)	*Sporobolus pyramidalis*	pulls cattle´s teeth (8) hard to chew (5) meat on neck of animals becomes harder (1) outcompetes other species (1)
Omutete (6)	*Cymbopogon afronardus*	sharp edges injure cow´s lips/mouths (2) outcompetes other plants (2) hideout for ticks and tse tse flies (1)
Ekicuguza-Mbogo (2)	*n.s.*	causes diarrhoea (1)
Ekihuki (1)	*Lantanta camara*	poisonous (1) causes photosensitivity (1)
Kagyenz'enda (1)	*n.s.*	thorny plant (1)
Eyojwa (1)	*Themeda triandra*	
Marende (1)	*n.s.*	causes diarrhoea (1)

7 plants were mentioned by farmers. Plants being most frequently described as “bad” were “Egashi” (*Sporobolus pyramidalis;* by all farmers), “Omutete” (*Cymbopogon afronardus;* 60%) and “Ekicuguza-Mbogo” (*n.s.*) (20%).

10 qualities were ascribed to “bad” plants. Qualities being described most frequently as bad were (in brackets times mentioned): pulling out cattle´s teeth (8), being hard to chew (5) and outcompeting other plants (3). Interestingly “Marende”, which has also been described as a “good” plant by one farmer was considered a “bad” plant by a different farmer.

4.2.3. Changes of vegetation on crossbred pastures

Farmers interviewed have been keeping crossbred cattle separated from Ankole cattle between 8 and 22 years.

On 60% of crossbred pastures bushes and shrubs have increased, on 40% decreased during the last 10 years (Fig. 41). Farmers estimated a lot of increase for 50% of pastures concerned and a moderate to lesser extent of increase for the rest of crossbred pastures.

On 50% of crossbred pastures trees have increased, on 50% decreased over the last 10 years (Fig. 41). The extent to which trees have increased was described as a lot for 20% and as moderate or to lesser extent for the rest of crossbred pastures (40% respectively).

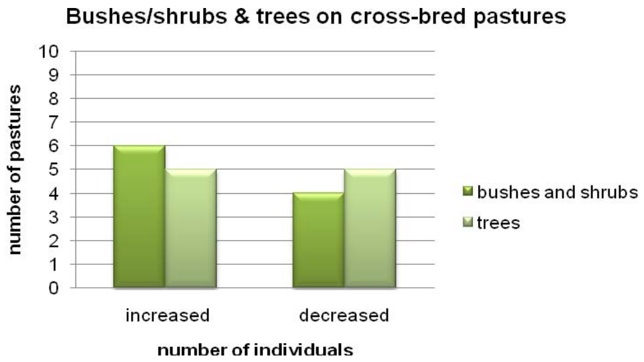

Fig. 41 Changes in bushes/shrubs and trees on crossbred pastures

As reasons why trees have decreased farmers mentioned that trees have been cleared (80%) or unreliable rains were to be blamed for the decrease.

Farmers were asked to name plants causing most problems on crossbred pastures (Table 17). 9 plants were mentioned to cause problems in crossbred pastures. “Omuteete” (Cymbopogon afronardus), “Egashi” (Sporobolus pyramidalis) and “Ekihuki” (Lantana camara) were named most frequently. 4 of the plants mentioned, were not mentioned to cause problems on Ankole pastures. 1 farmer said that 1 species (“Egashi”) was only found on his crossbred pasture and not on his Ankole pasture.

On 1 crossbred pasture “Omutete”(*Cymbopogon afronardus)* and shrubs do not occur. A different farmer mentioned, that certain species were found more frequently on his Ankole pasture than on his crossbred pasture. 11 different problems caused by plants on crossbred pastures were named.

Most frequently named were (in brackets times mentioned): outcompetes other species (5), unpalatable (2) and multiplies fast (2).

Table 17. Plants causing problems on crossbred pastures

local name (times mentioned)	botanical name	problem caused
Omuteete (5)	*Cymbopogon afronardus*	unpalatable injures animals´ mouths multiplies fast sprouts very fast hideout for parasites and tsetse flies
Egashi (4)	*Sporobolus pyramidalis*	hard to feed on removes animals´ teeth
Ekihuki (4)	*Lantana camara*	unpalatable multiplies fast outcompetes other plants causes photosensitivity
Kagyenz'enda (2)	*n.s.*	outcompetes other plants thorny, spreads over palatable plants
Entengotengo (1)	*n.s.*	poisonous
Ekishekesheke (1)	*n.s.*	outcompetes other species
Sodoms apple (1)	*Cynodon dactylon*	n.s.
Omugahsa (1)	*n.s.*	outcompetes other plants
Omutungu (1)	*n.s.*	outcompetes other plants

4.2.4. Changes of vegetation on Ankole pastures

For most farmers it was hard to say for how long they have been grazing Ankole cattle on separated pastures. 7 answered they were keeping Ankole for a long time. 3 farmers were more specific. Time span during which they have been stocking certain pastures only with Ankole cattle varied from 4 to 15 years.

An increase of bushes and shrubs over the last 10 years has been noticed on 60% of Ankole pastures (Fig. 42).

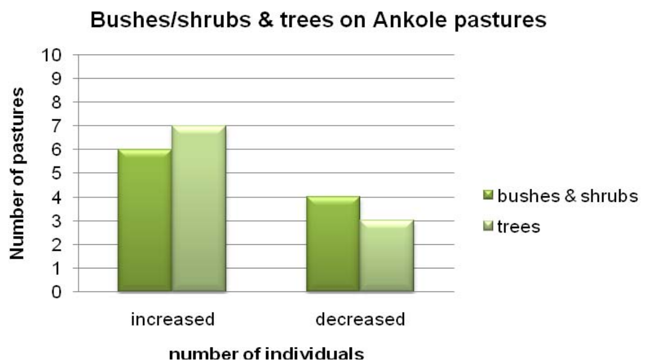

Fig. 42 Changes in bushes/shrubs and trees on Ankole pastures

On 40% a decrease has been noticed. Among pastures with an increase 14% were affected to a lesser extent, 57% to a moderate extent and 29% to a great extent. 2 farmers said explicitly, that bushes and shrubs decreased because of regular bush clearing activities. 70% said that on Ankole pastures trees have increased during the last 10 years. 30% said, trees had decreased during past decade. The extent to which trees have increased was described as a lot for 29%, as moderate for 57% and as little for 14%. 1 farmer mentioned trees in his Ankole pasture were increasing although he would regularly perform bush clearing.

Reasons for a decrease of trees were regular clearing of trees (leaving out leguminous trees) (3) or unreliable rains. One farmer explained increase of trees in his Ankole pasture by saying, that Ankole cattle was not affected by trees but used them to sharpen their horns.

Plants causing most problems on Ankole pastures were listed and described (Table 18). Plants and problems mentioned were similar to those on crossbred pastures. Plant species most frequently named were the same as on crossbred pastures. 6 plant species were mentioned. Fewer species than for crossbred pastures. 1 species caused problems on Ankole pastures that was not mentioned for crossbred pasture ("Oumjaja"). 9 farmers said no plants could be found on their Ankole pastures that could not also be found on their crossbred pasture.

Table 18. Plants causing problems on Ankole pastures

local name (times mentioned)	*botanical name*	causes which problem
Omuteete (5)	*Cymbopogon afronardus*	injures animals´ mouths
		hideout for parasites, snakes and tsetse flies
		wastes land
		unpalatable
Ekihuki (4)	*Lantana camara*	outcompetes other species
		causes photosensitivity
Egashi (2)	*Sporobolus pyramidalis*	unpalatable
Kagyenz'enda (2)		outcompetes other species
		thorny, spreads over palatable plants
Oumjaja (1)	*n.s.*	outcompetes other species
Omutungu (1)	*n.s.*	outcompetes other species
		difficult to eradicate

8 different problems were mentioned to occur on Ankole pastures caused by these plants. Fewer problems than on crossbred pastures. Problems most frequently mentioned were (in brackets number of times mentioned): outcompetes other plants (4) and unpalatable (2). All other problems were just mentioned once.

4.3. Results of plant identification

Farmers were asked to identify individual plants collected around transect sites. Resulting list of local names was later, where possible, completed with botanical and common English names (Table 19).

On 6 farms plants were collected for identification. Mostly plant identification was done during second round of data collection. Some farmers were not present when pasture samples were taken and no appropriate substitute could be found.

This information was only collected additionally as botanical description of pastures was no objective of this thesis. For some plants more than one local name was given. Plants were identified by farmers, or other competent persons.

Farmers were asked to specify qualities of the plants presented to them. 31 plants were collected. For 18 plants different qualities were mentioned by different farmers, for 13 plants no particular qualities were mentioned at all. 10 "good" and "bad" plants were mentioned respectively. The other 11 plants were not classified either "good" or "bad". 16 different qualities were ascribed to the collected plants.

Dominant species were similar across all 10 farms, according to visual impression. It was not considered necessary to collect the same species just for the sake of identifying them. It was not specified on which pastures plants for identification were collected.

Table 19. Selected pasture plants from transect sites and their qualities

local name	correct spelling	botanical name	English name	plant quality	detailed quality
Akanyarutoshi	Akanyarutokye	*n.s.*	*n.s.*	good	highly nutritive
Ebikamba	Ebikamba	*Macroptilim atropurpureum*	Green leaf desmodium	n.s.	n.s.
Egashi/Egaashi	Egashi	*Sporobolus pyramidalis*	Sporobolus	bad	weed, only eaten when no alternative, drought resistant , difficult to chew, causes detoothing
Ejubwe / Eshubwe/ Kishubwe/ Kijubwe	Ekijubwe	*Brachiaria sp.*	Signal grass	good	very good plant, highly nutritive, very palatable, not so much eaten
Ekihuki/Ekiwuki	Ekihuki	*Lantana camara*	Lantana - hedges	bad	weed
Ekikuguzambogo/ Ekikyuguzambogo	Ekicuguza-Mbogo	*n.s.*	*n.s.*	n.s.	n.s.
Ekiraguzo (shrub)		*n.s.*	*n.s.*	bad	unpalatable
Ekishekaeheke	Ekishekesheke	*n.s.*	*n.s.*	n.s.	n.s.
Elazi/Erazi	Erazi	*n.s.*	*n.s.*	bad	unpalatable/ palatable but not much eaten
Emburara	Emburara	*Hyparrhenia rufa*	Thatching grass	good	very good plant, used to be very common: due to selective grazing becoming extinct, highly nutritive, drought resistant, very soft
Engunga	Egunga	*n.s.*	*n.s.*	n.s.	n.s.
Entengotengo	Entengotengo	*n.s.*	*n.s.*	n.s.	n.s.
Entobotobo/ Kitabotobo	Entobotobo	*Solanum aculeatissimum Jacq.*	soda apple nightshade	bad	unpalatable
Esonzi	Esonzi	*n.s.*	*n.s.*	n.s.	n.s.
Eyojo	Eyojo	*n.s.*	*n.s.*	good	n.s.
Eyojwa/Eyozwa	Eyojwa	*Themeda triandra*	Grader grass	n.s.	n.s.
Kagyenzanda/ Kagyenzenda/ Kagyezabda	Kagyenz'enda	*n.s.*	*n.s.*	n.s.	n.s.
Kanyamunyo/ Olutokyelwa	Orutokye-rwa-kanyamunyu	*n.s.*	*n.s.*	good	pleasant smell (fruit used as perfume by women), nutritious
Kayitabuteme	Kayitabuteme	*n.s.*	*n.s.*	n.s.	n.s.
Kayukiyuk	Kayukiyuk	*n.s.*	*n.s.*	bad	unpalatable
Kibogote	Kibogote	*n.s.*	*n.s.*	bad	unpalatable
Kyoya	Kyooya	*n.s.*	*n.s.*	good	n.s.
Malende/Marende	Marende	*n.s.*	*n.s.*	good	nutritious
Mwenyi	Mwenyi	*n.s.*	*n.s.*	bad	unpalatable
Omugasha	Omugasha	*n.s.*	*n.s.*	n.s.	n.s.
Omunyontole	Omunyontole	*n.s.*	*n.s.*	good	highly palatable
Omutete/Mutete	Omuteete	*Cymbopogon afronardus*	Lemon grass	bad	unpalatable, only eaten when still young, difficult to weed
Omutungu	Omutungu	*n.s.*	*n.s.*	n.s.	n.s.
Omwengi	Omwengi	*n.s.*	*n.s.*	bad	unpalatable
Orukwamba/Luchwamba/ Kifuta	Oruchwamba	*Cynodon dactylon*	Star grass	good	not drought resistant, sprouts very fast, nutritious
Orunyankokole/ Orunyankokore/ Runyunkokore/ Olunyankokole/ Ehunyankokole	Orunyankokole	*Chloris gayana*	Rhodes grass	good	nutritious

4.4. Results of pasture analyses

Includes results of trait transects, pasture productivity and plant identification.

4.4.1. Results of trait transects

Trait transect results are divided into results of continuous and discontinuous traits. 3750 plants were measured in total. Observations used for statistical analysis vary according to trait (Table 20).

Table 20. Observations used for statistical analysis per farm and breed

	observations used							
farm	**plant height, cm**	**reproductive heigth, cm**	**leaf width, mm**	**leaf length, mm**	**life form**	**growth form**	**clonality**	**spinenes-cence**
1	181	11	181	181	181	181	181	181
2	451	11	447	451	448	451	451	451
3	381	40	381	381	380	381	381	381
4	360	14	359	359	360	360	360	360
5	376	27	376	376	375	376	376	376
6	485	41	485	486	485	486	486	485
7	445	49	445	445	444	444	443	444
8	351	46	350	350	350	351	351	351
9	352	60	351	350	351	350	351	351
10	368	37	368	368	366	368	368	368
breed								
Ankole	1715	161	1715	1715	1710	1715	1714	1714
crossbred	2035	175	2032	2032	2030	2033	2034	2034
total	3750	336	3747	3747	3740	3748	3748	3748

More plants were measured on crossbred than on Ankole pastures (+320 individuals or 8,5%). Plant numbers measured on Ankole pastures ranged from 84 to 233 individuals with a mean of 171.6. Plant numbers on crossbred pastures ranged from 98 to 270 with a mean of 203.7.

4.4.1.1. Results for continuous traits

Continuous traits analysed are: plant height in cm (4.1.1.1.1), reproductive height in cm (4.1.1.1.2), leaf width in mm (4.1.1.1.3), leaf length in mm (4.1.1.1.4). All diagrams include standard errors.

4.1.1.1.1 Plant height

Statistical model for analysis of plant height has a R-Square of 0.11. Coefficient of variation is 66.14. Square root MSE is 14.36. Pr > F of the model is <.0001. 21.70cm was calculated to be overall LSMEAN plant height.

Fixed effect farm has a highly significant influence on plant height (Pr > F = <.0001). Significantly different farms are indicated with superscripts (Table 21, Fig. 43).

3750 plants were measured for plant height. Plant numbers per farm range from 181 individuals (farm 1) to 485 individuals (farm 6) (mean of 375, median 372). Difference between smallest and largest number of plants measured is 304 (8,1% of all plants measured).

Farm mean plant heights range from 17.77cm (farm 4) to 25.68cm (farm 1) (median plant: 21.99cm).

Table 21. Farm mean plant heights in cm

farm	n	plant height, cm LSMEANS	stderr.
1	181	25.68^{achij}	± 1.07
2	451	21.20^{bdj}	± 0.69
3	381	22.57^{acj}	± 0.74
4	360	19.70^{bd}	± 0.76
5	376	25.64^{acfhij}	± 0.75
6	485	17.77^{bdefgh}	± 0.65
7	445	22.33^{adj}	± 0.68
8	351	22.23^{acj}	± 0.78
9	352	21.75^{adj}	± 0.77
10	368	21.16^{bdj}	± 0.75
all	3750	21.70	

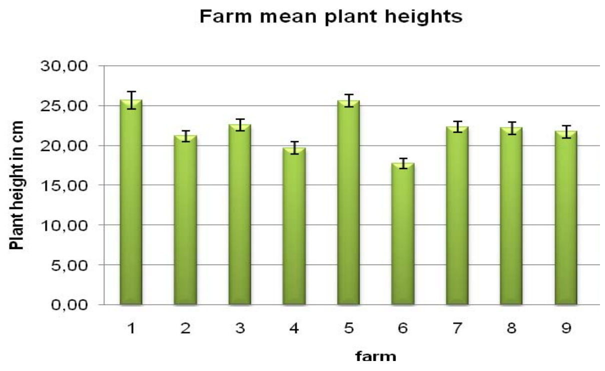

Fig. 43 Farm mean plant heights in cm

Table 22. Breed mean plant height

breed	n	plant height, cm LSMEANS	stderr.
Ankole	1715	18.97^{a}	± 0.36
cross bred	2035	25.04^{b}	± 0.33

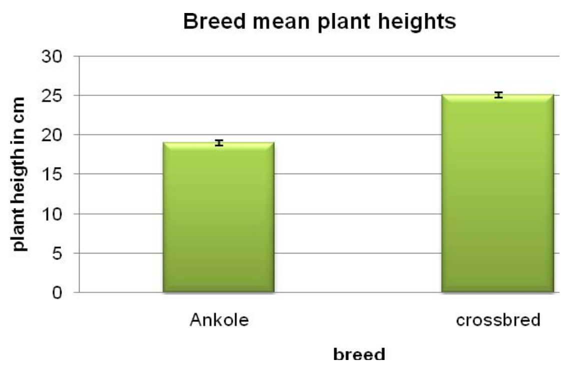

Fig. 44 Breed mean plant heights in cm

Fixed effect breed has a highly significant influence on plant height (Pr > F = <.0001). Significant difference is indicated by superscripts (Table 22, Fig. 44). More plants from crossbred pastures (2035) were measured than from Ankole pastures (1715). The difference is 320 individuals (8,5% of all plants measured). Mean plant height for Ankole pastures is 18.97cm. Mean plant height for crossbred pastures in 25.04cm. The difference in mean plant height between breeds is 6.07cm.

Table 23. Pasture mean plant heights in cm

	Ankole			crossbred		
farm	**n**	**plant height, cm LSMEANS**	**stderr**	**n**	**plant height, cm LSMEANS**	**stderr**
1	84	13.91^{a}	±1.57	97	37.46^{b}	±1.46
2	181	24.15^{a}	±1.07	270	18.25^{b}	±0.87
3	166	16.97^{a}	±1.11	215	28.17^{b}	±0.98
4	167	19.52	±1.11	193	19.87	±1.03
5	215	18.49^{a}	±0.98	161	32.80^{b}	±1.13
6	233	15.87	±0.94	252	19.66	±0.90
7	201	16.10^{a}	±1.01	244	28.57^{b}	±0.92
8	140	23.66	±1.21	211	20.79	±0.99
9	150	20.81	±1.17	202	22.70	±1.01
10	178	20.18	±1.08	190	22.14	±1.04

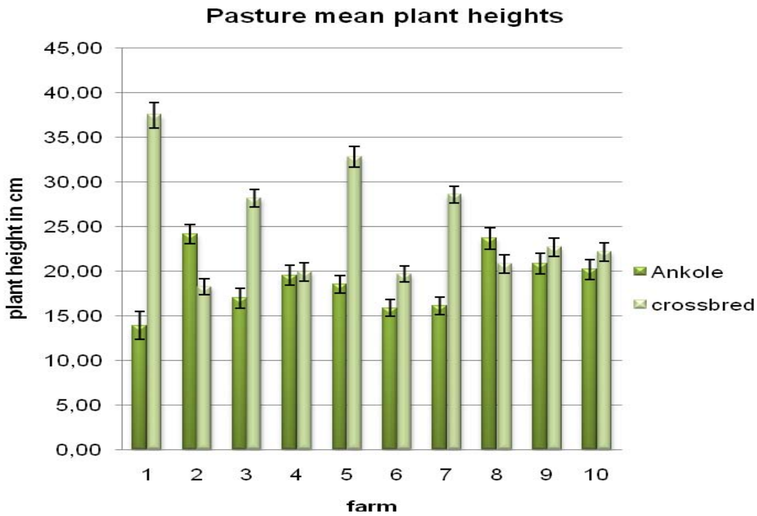

Fig. 45 Pasture mean plant heights in cm

Interaction of farm and breed does have a significant influence on plant height (Pr > F = <.0001). If pastures on 1 farm are significantly different, this difference is indicated by superscripts 'a' and 'b' for every farm concerned. (Table 23, Fig. 45). Plants measured range from 84 individuals (Ankole pasture, farm 1) to 270 individuals (crossbred pasture, farm 2) (mean: 188, median: 191). On Ankole pastures between 84 (farm 1) an 233 (farm 6) individuals were measured. On crossbred pastures between 97 (farm 1) and 270 (farm 2) individuals were measured. Difference in plants measured between breeds was 32 individuals (0.9%). (mean: 172 on Ankole, 204 on crossbred pastures; median: 172.5 on Ankole, 205 on crossbred pastures).

Pasture mean plant heights range between 13.91cm (Ankole pasture, farm 1) and 37.46cm (crossbred pasture, farm 1). Mean plant heights on Ankole pastures range between 13.91cm and 24.15cm (mean: 18.97cm, median: 19.00cm). Mean plant heights on crossbred pastures range between 18.25cm and 37.46cm (mean: 25.04cm, median: 22.42cm). All values are larger for plants measured on crossbred pastures. There is a significant difference in plant height between Ankole and crossbred pasture on farms 1, 2, 3, 5 and 7.

4.1.1.1.2 Reproductive height

Statistical model for analysis of reproductive height has a R-Square of 0.13. Coefficient of variation is 75.55. Square root MSE is 26.76. Pr > F of the model is 0.0006. 35.42cm was calculated to be the overall LSMEAN reproductive height.

Fixed effect farm has a significant influence on reproductive height (Pr > F = 0.0012). Significantly different farms are indicated by superscripts (Table 24, Fig. 46). Of all plant traits reproductive height could be measured on the smallest number of plants (336: 8.96% of all plants measured). Plant numbers measured per farm range from 11 (farm 1, farm 2) to 60 individuals (farm 9) (mean 33.6; median: 38.5). Difference between smallest and largest number of plants per farm is 49. Farm mean reproductive heights range from 22.18cm (farm 3) to 55.46cm (farm 1) (median: 34.4cm). The difference from smallest to largest mean reproductive height is 33.28cm.

Table 24. Farm mean reproductive heights in cm

farm	n	reproductive height, cm LSMEANS	stderr.
1	11	55.46[ac]	± 8.39
2	11	34.62[ac]	± 8.10
3	40	22.18[bd]	± 4.52
4	14	30.71[ac]	± 7.15
5	27	39.32[ac]	± 5.64
6	41	28.25[ad]	± 4.49
7	49	32.31[ac]	± 3.92
8	46	36.58[ac]	± 4.14
9	60	46.58[ac]	± 3.59
10	37	34.17[ac]	± 4.44
all	336	35.42	

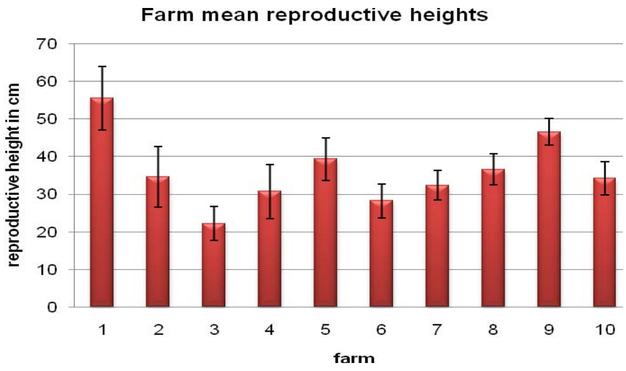

Fig. 46 Farm mean reproductive heights in cm

Table 25. Breed mean reproductive heights in cm

breed	n	reproductive height, cm LSMEANS	stderr.
Ankole	161	30.51[a]	± 2.65
cross bred	175	41.52[b]	± 2.44

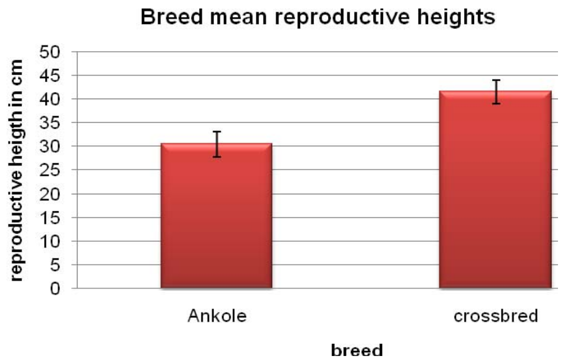

Fig. 47 Breed mean reproductive heights in cm

Fixed effect breed has a significant influence on reproductive height (Pr > F = 0.0025). The significant difference between breeds is indicated by superscripts (Table 25, Fig. 47). The number of plants with inflorescences was higher on crossbred (175 individuals) than on Ankole pastures (161 individuals) with a difference of 14. Mean breed reproductive height was 30.51cm on Ankole and 41.52cm on crossbred pastures. The difference between breeds is 11.01cm. Plant number and mean plant height are higher on crossbred pastures.

Interaction of farm and breed does not have an influence on reproductive height (Pr > F = 0.6376) (Table 26, Fig. 48). Plant numbers per pasture range from 4 (farm 1, Ankole pasture) to 38 (farm 9, Ankole pasture) individuals (mean: 16.80, median: 16). Plant numbers on Ankole pastures range from 4 (farm 1) to 38 (farm 9) individuals (mean: 16.10, median: 14.50). Plant numbers on crossbred pastures range from 6 to 30 individuals (mean 17.50, median: 20).

Pasture mean reproductive heights for all pastures range from 18.19cm to 68.29cm (mean 36.02cm, median: 34.61cm). Pasture reproductive heights on Ankole pastures range from 18.19cm to 46.29cm (mean 30.51cm, median: 28.70cm). Pasture reproductive heights on crossbred pastures range from 26.16cm to 68.29cm (mean 41.52cm, median: 38.45cm).

Table 26. Pasture mean reproductive heights in cm

farm	n	Ankole repr. height, cm LSMEANS	stderr	n	crossbred repr. height, cm LSMEANS	stderr.
1	4	42.63	± 13.38	7	7	± 10.12
2	5	36.10	± 11.97	6	6	± 10.93
3	13	18.19	± 7.42	27	27	± 5.15
4	7	21.94	± 10.12	7	7	± 10.12
5	19	25.52	± 6.14	8	8	± 9.46
6	13	26.17	± 7.42	28	28	± 5.06
7	30	28.53	± 4.89	19	19	± 6.14
8	16	28.86	± 6.69	30	30	± 4.89
9	38	46.29	± 4.34	22	22	± 5.71
10	16	30.91	± 6.69	21	21	± 5.84

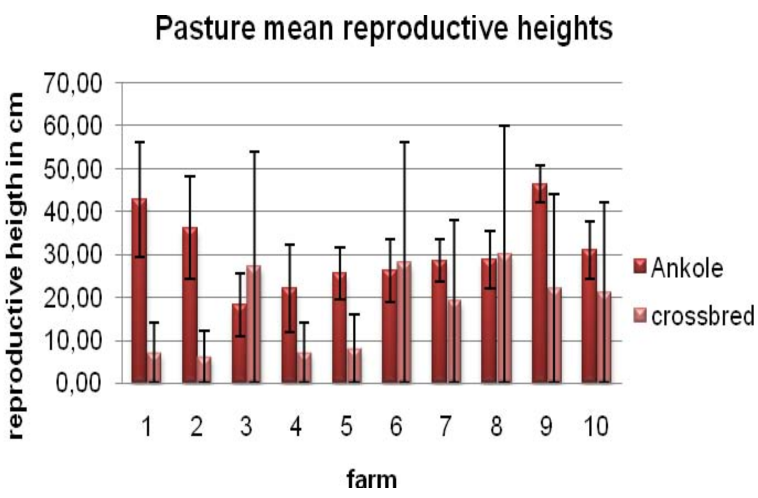

Fig. 48 Pasture mean reproductive heights in cm

4.1.1.1.3 Leaf width

Statistical model for analysis of leaf width has a R-Square of 0.09. Coefficient of variation is 68.83. Square root MSE is 4.67. Pr > F of the model is <.0001. 6.79mm has been calculated to be to overall leaf width LSMEAN.

Fixed effect farm has a highly significant influence on leaf width (Pr > F= <.0001). Significantly different farms are indicated with superscripts (Table 27, Fig. 49).

3747 plants were measured. Plant numbers range from 181 individuals (farm 1) to 485 individuals (farm 6) (mean: of 374.3, median: 372).

Difference between smallest and largest number of plants is 304 (8,1%). Farm mean leaf widths range from 5.02mm (farm 2) to 8.66mm (farm 4) (mean 6.79cm, median: 6.33cm). Difference between smallest and largest mean leaf widths is 3.64mm.

Table 27. Farm mean leaf widths in mm

farm	n	leaf width, mm LSMEANS	stderr.
1	181	5.18^{bde}	± 0.35
2	447	5.02^{bdef}	± 0.22
3	381	7.72^{acfgh}	± 0.24
4	359	8.66^{acefgh}	± 0.25
5	376	5.98^{bde}	± 0.24
6	485	6.43^{bdh}	± 0.21
7	445	8.44^{acefgh}	± 0.22
8	350	6.23^{bdh}	± 0.25
9	351	7.16^{bcgh}	± 0.25
10	368	6.23^{bdh}	± 0.24
all	3747	6.79	

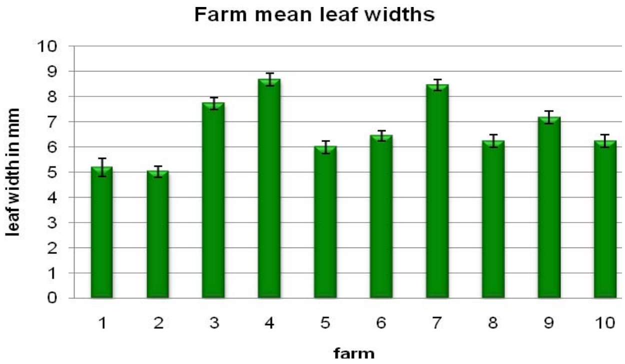

Fig. 49 Farm mean leaf widths in mm

Fixed effect breed does not have a significant influence on leaf width. (Pr > F = 0.5418) (Table 28, Fig. 50). More plants were measured on crossbred pastures (2032) than on Ankole pastures (1715). The difference in plant numbers between breeds is 317 individuals (8,5%). Mean leaf width on Ankole pastures was 6.75mm, on crossbred pastures 6.66mm. The difference of mean leaf widths between breeds is 0.09mm.

Table 28. Breed mean leaf widths in mm

breed	n	leaf width, mm LSMEANS	stderr.
Ankole	1715	6.75	± 0.12
cross bred	2032	6.66	± 0.11

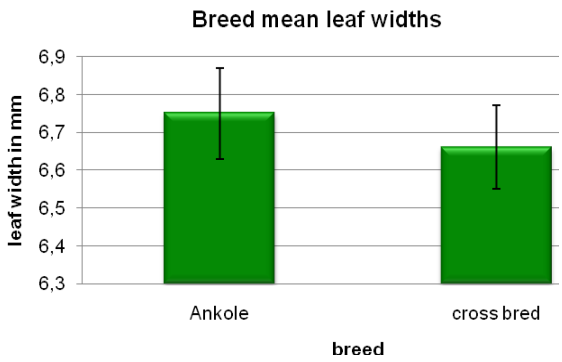

Fig. 50 Breed mean leaf widths in mm

Interaction of farm and breed does have a highly significant influence on plant height (Pr > F = <.0001). Significant difference between Ankole and crossbred pastures on a farm are indicated by superscripts 'a' and 'b' (Table 29, Fig. 51).

Plant numbers per pasture range from 84 (farm 1, Ankole pasture) to 270 (farm 2, crossbred pasture) individuals (mean: 187, median: 191). Plants measured on Ankole pastures range from 84 (farm 1) to 233 (farm 6) individuals (mean: 171.50, median: 179.50). Plants numbers on crossbred pastures range from 97 (farm 1) to 270 (farm 2) (mean: 203.2, median: 210). Plant numbers were higher on crossbred pastures. Mean pasture leaf widths for all pastures range from 4.20mm to 9.71mm (mean: 6.70, median: 6.88). Mean pasture leaf widths on Ankole pastures range from 4.20mm to 8.18mm (mean: 6.75, median: 7.38). Mean pasture leaf widths on crossbred pastures range from 4.48mm to 9.71mm (mean: 6.66, median: 6.47). Mean leaf widths was larger on crossbred pastures. Significant differences in leaf width between Ankole and crossbred pastures can be found on farms 2, 4, 5, 6 and 8.

Table 29. Pasture mean leaf widths in mm

farm	n	Ankole leaf width, mm LSMEANS	stderr	n	crossbred leaf width, mm LSMEANS	stderr.
1	84	5.51	± 0.51	97	4.85	± 0.47
2	181	4.20[a]	± 0.35[b]	270	5.85	± 0.28
3	166	7.93	± 0.36	215	7.51	± 0.32
4	167	7.61 [a]	± 0.36 [b]	192	9.71	± 0.34
5	215	7.48 [a]	± 0.32 [b]	161	4.48	± 0.37
6	233	5.26 [a]	± 0.31 [b]	252	7.59	± 0.29
7	201	8.18	± 0.33	244	8.70	± 0.30
8	140	7.28 [a]	± 0.39 [b]	210	5.18	± 0.32
9	150	8.10	± 0.38	201	6.21	± 0.33
10	178	5.99	± 0.35	190	6.47	± 0.34

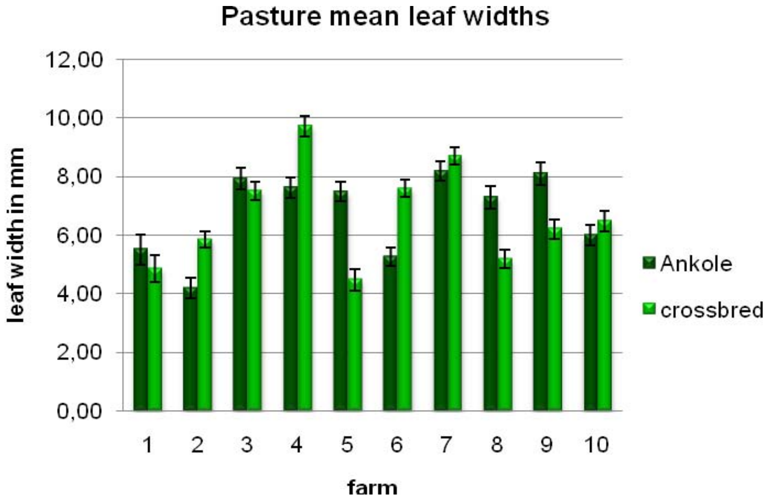

Fig. 51 Pasture mean leaf widths

4.1.1.1.4 Leaf length

Statistical model for analysis of leaf length has an R-Square of 0.10. Coefficient of variation is 85.05. Square root MSE is 87.37. Pr > F of the model is <.0001. 102.74mm was calculated to be the overall LSMEAN leaf length.

Fixed effect farm has a highly significant influence on leaf length (Pr > F= <.0001). Significantly different farms are indicated with superscripts (Table 30, Fig. 52). 3747 plants were measured for leaf length. Number of plants per farm range from 181 (farm 1) to 486 (farm 6) (mean: 374.7, median: 372). Difference between smallest and largest number of plants is 305 (8,1%). Mean leaf length by farm range from 81.46mm (farm 4) to 139.1mm (farm 1) (mean: 102.74mm, median: 101.71mm). Difference between smallest and largest mean leaf length is 57.64mm.

Fixed effect breed has a highly significant influence on leaf length (Pr > F= <.0001). The significant difference between breeds is indicated with superscripts (Table 31, Fig. 53). More plants were measured on crossbred (2032) than on Ankole pastures (1715). The difference in plant numbers between breeds is 317 (8,5%). Mean leaf length on Ankole pastures was 89.12mm, on crossbred pastures 121.65mm. Difference in mean leaf length between breeds is 32.53mm.

Table 30. Farm mean leaf lengths in mm

farm	n	leaf length, mm LSMEANS	stderr.
1	181	139.1[acegi]	± 6.51
2	451	97.08[bdfhj]	± 4.20
3	381	93.14[bdfhj]	± 4.51
4	359	81.46[bcfhj]	± 4.62
5	376	136.9[acegi]	± 4.55
6	486	92.33[bdfhj]	± 3.97
7	445	89.84[bcfhj]	± 4.16
8	350	106.52[bdfhi]	± 4.77
9	350	106.34[bdfhi]	± 4.72
10	368	111.16[bdfgi]	± 4.56
all	3747	102.74	

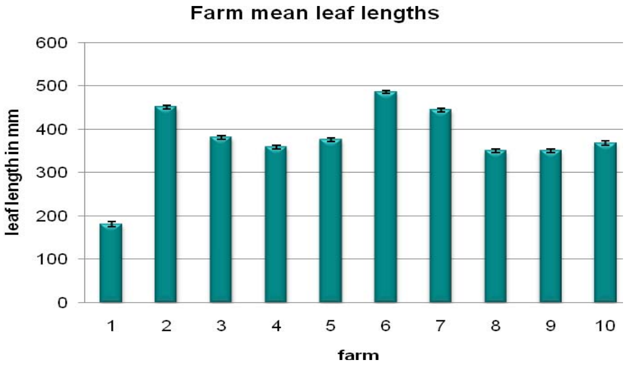

Fig. 52 Farm mean leaf lengths in mm

Table 31. Breed mean leaf lengths in mm

breed	n	leaf length, mm LSMEANS	stderr.
Ankole	1715	89.12[a]	± 2.19
cross bred	2032	121.65[b]	± 2.02

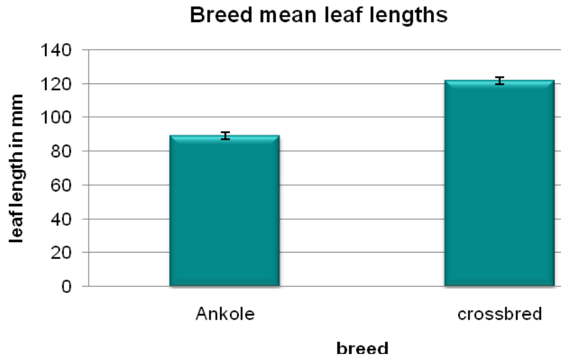

Fig. 53 Breed mean leaf lengths in mm

Interaction of farm and breed has a highly significant influence on leaf length (Pr > F = <.0001). Significant differences amongst Ankole and crossbred pasture on a single farm are indicated by superscripts “a” and “b”. (Table 32, Fig. 54).

Plant numbers per pasture range from 84 (farm 1, Ankole pasture) to 270 (farm 2, crossbred pasture) (mean: 187.5, median: 191). Plant numbers on Ankole pastures range from 84 (farm 1) to 233 (farm 6) (mean: 171.5, median: 172.5). Plant numbers on crossbred pastures range from 97 (farm 1) to 270 (farm 2) (mean: 203.2, median: 205). More plants were measured on crossbred pastures.

Mean pasture leaf lengths range from 63.3mm (farm 1, Ankole pasture) to 214.88mm (farm 1, crossbred pasture) (mean: 105.39mm, median: 98.22mm). Pasture leaf lengths on Ankole pastures range from 63.3mm (farm 1) to 89.12mm (farm 8) (mean: 89.12mm, median: 89.87mm). Pasture leaf lengths on crossbred pastures range from 81.91mm (farm 4) to 214.88mm (farm 1) (mean: 121.65mm, median: 108.44mm). There are significant differences in leaf length between Ankole and crossbred pasture of farms 1, 3, 5 and 7.

Table 32. Pasture mean leaf lengths in mm

farm	n	Ankole leaf length, mm LSMEANS	stderr	n	crossbred leaf length, mm LSMEANS	stderr
1	84	63.3[a]	9.53	97	214.88[b]	8.87
2	181	107.21	6.49	270	86.95	5.32
3	166	75.51[a]	6.78	215	110.76[b]	5.96
4	167	81.00	6.76	192	81.91	6.31
5	215	88.71[a]	5.96	161	185.08[b]	6.89
6	233	91.03	5.72	253	93.63	5.49
7	201	73.57[a]	6.16	244	106.12[b]	5.59
8	140	110.23	7.38	210	102.81	6.03
9	150	92.74	7.13	200	119.95	6.18
10	178	107.89	6.55	190	114.42	6.34

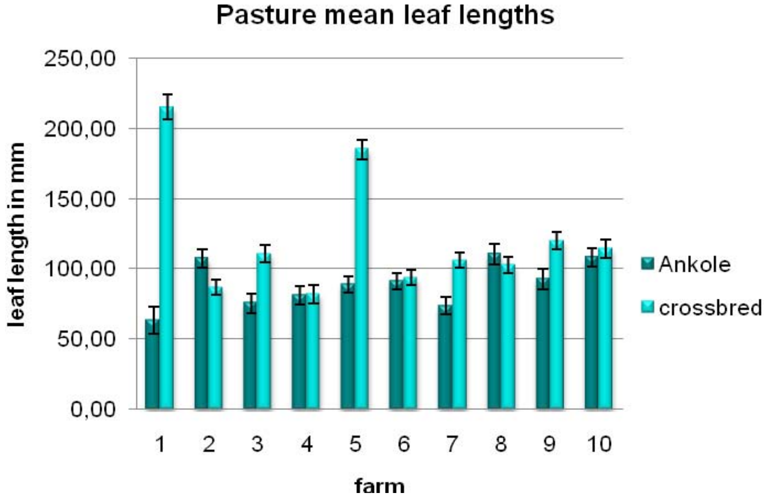

Fig. 54 Pasture mean leaf length in mm

4.4.1.2. Results for discontinuous traits

Frequencies and percentages were analysed for all pastures and also for each breed separately. Discontinuous traits analysed are: life form (4.1.1.1.5), growth form (4.1.1.1.6), clonality (4.1.1.1.7), spinescence (4.1.1.1.8).

4.1.1.1.5 Life form

Three different life form categories were defined (Table 33). Details on categories can be found in chapter 2.8.4.

Table 33. Frequencies and percentages of life forms

life form	frequencies all (n=3740)	frequencies Ankole (n=1710)	frequencies crossbred (n=2030)	percentages all	percentages Ankole	percentages crossbred
grass	3645	1663	1982	97.46	97.25	97.64
herb	91	47	44	2.43	2.75	2.17
legume	4	0	4	0.11	0.00	0.20

On all pastures 3740 plants were classified for life form. More plants on crossbred (2030) than on Ankole pastures (1710). Difference in plant numbers is 320 or (+8.6%). Grasses were by far the dominant life form in both pasture types. 1663 plants on Ankole pastures and 1982 plants on crossbred pastures were grasses. Second most frequent life from were herbs with 47 plants on Ankole pastures and 44 plants on crossbred pastures. Legumes were found only on crossbred pastures and in total only 4 plants were classified as legumes.

The dominance of grasses is also obvious when it comes to percentages of different life forms. 97.25% of plants on Ankole pastures and 97.64% of plants on crossbred pastures are grasses. A higher percentage on crossbred pastures. 2.75% of plants on Ankole pastures to 2.17% of plants on crossbred pastures were herbs. A higher percentage on Ankole pastures. 0.20% of plants on crossbred pastures were legumes. Of all plants classifies, legumes made up only 0.11%.

4.1.1.1.6 Growth form

Seven different growth from categories were found (Table 34): short basal, long basal, semi basal, erect leafy, cushions, tussocks and climbers & scramblers. Growth forms are described in chapter 2.8.5.

Table 34. Frequencies and percentages of growth forms

	frequencies			percentages		
growth form	**all** (n=3748)	**Ankole** (n=1715)	**crossbred** (n=2033)	**all**	**Ankole**	**crossbred**
short basal	1993	908	1085	53.18	52.94	53.57
long basal	2	0	2	0.05	0.00	0.10
semi basal	6	3	3	0.16	0.17	0.15
erect leafy	763	360	403	20.36	20.99	19.82
cushions	1	0	1	0.03	0.00	0.05
tussocks	979	443	536	26.12	25.83	26.36
climbers & scramblers	4	1	3	0.11	0.06	0.15

3748 plants were classified for growth form. Most frequent growth forms found were the same for both pasture types (short basal (1993 plants), tussock (979 plants) and erect leafy (763 plants)). More plants were classified on crossbred (2033) than on Ankole pastures (1715) (+318 or 8.49%).

Short basal was the dominant growth form. 908 plants on Ankole and 1085 plants on crossbred pastures fell into this category. Second most frequent growth form was tussock with 443 plants on Ankole and 536 plants on crossbred pastures. Third most frequent growth form was erect leafy with 360 plants on Ankole and 403 plants on crossbred pastures.

Other growth forms that could be found were covered by less than 7 plants respectively on both pastures. Long basal and cushion growth forms could only be identified on crossbred pastures. Number of different growth forms was larger on crossbred pastures.

Considering percentages more than half of all plants fall into the short basal category (52.94% on Ankole, 53.57% on crossbred pastures). Slightly more plants from crossbred pastures belong to this category (+ 0.63%). The 2nd most frequent growth form tussock was represented by 25.83% of plants from Ankole and 26.36% of plants from crossbred pastures. Slightly more plants from crossbred pasture belong to this category (+0.53%). Erect leafy, 3rd most frequent growth form, was represented by 20.99% of plants from Ankole and 19.82% of plants from crossbred pastures. Slightly more plants from Ankole pastures belonged to this category (+ 1.17%). All other growth form categories covered less than 0.20 % of all plants classified.

4.1.1.1.7 Clonality

Clonality was divided into two classes: clonal and not clonal (Table 35) (categories are described in chapter 0.).

Table 35. Frequencies and percentages of clonality

clonality	frequencies			percentages		
	all (n=3748)	Ankole (n=1642)	crossbred (n=2034)	all	Ankole	crossbred
not clonal	3721	1619	2030	99.28	98.66	99.80
clonal	27	23	4	0.72	1.34	0.20

3748 plants were classified for clonality. Most plants were not clonal (3721). Only 27 plants were clonal. More plants were classified on crossbred (2034) than on Ankole pastures (1642) (+411 plants or +11.95%). 1619 plants from Ankole and 2030 plants from crossbred pastures were classified as not clonal. 23 plants from Ankole and 4 plants from crossbred pastures were classified as clonal.

In percentages category not clonal was represented by 98.66% of plants from Ankole and by 99.80% of plants from crossbred pastures. Slightly more not clonal plants were found on crossbred pastures (+1.14%). Category clonal was represented by 1.34% of plants from Ankole and 0.20% of plants from crossbred pastures. A much higher percentage of clonal plants was found on Ankole pastures (6.7 times as many). Although overall portion of clonal plants is minute.

4.1.1.1.8 Spinescence

4 different categories of spinescence were found (category 0,1,2 & 3 described in chapter 2.8.7.) (Table 36).

Table 36. Frequencies and percentages of spinescence

spinescence	frequencies			percentages		
	all (n=3748)	Ankole (n=1714)	crossbred (n=2034)	all	Ankole	crossbred
0	3738	1704	2034	99.73	99.42	100.00
1	7	7	0	0.19	0.41	0.00
2	1	1	0	0.03	0.06	0.00
3	2	2	0	0.05	0.12	0.00

3748 plants were classified for spinescence. Most plants were classified into category 0: no spines, thorns or prickles. More plants were classified from crossbred (2034) than from Ankole pastures (1714).

Most frequent category 0 was represented by 1704 plants from Ankole and 2034 plants from crossbred pastures. 3 other categories, only found on Ankole pastures, were represented by 10 plants (7 plants: category 1; 2 plants: category 3 and 1 plant : category 2).

In percentages 99.42% of plants from Ankole pastures belonged to category 0. 100% of plants from crossbred pastures belonged to category 0. The other categories were represented with 0.41% (category 1), 0.12% (category) 3 and 0.06% (category 2).

4.4.2. Results for pasture productivity

Pasture productivity results are differentiated into three categories: fresh matter yield in t/ha, dry matter yield in t/ha and dry matter content in percent. Results of 74 samples were analysed for fresh and dry matter yield. Results of 75 samples were analysed for dry matter content in %. All diagrams include standard errors.

4.4.2.1. Fresh matter yield

Statistical model for analysis of fresh matter yield in t/ha has an R-Square of 0.58. Coefficient of variation is 3.55. Square root MSE is 0.19. Pr > F of the model is 0.0198. 5.39t/ha was calculated to be overall LSMEAN for all samples.

Fixed effect farm has no significant influence on fresh matter yield (Pr > F = 0.4335) (Table 49, Fig. 55). Mean farm fresh matter yields range from 5.29t/ha (farm 3, farm 4) to 5.47t/ha (farm 5, farm 7) (mean: 5.387t/ha, median: 5.395t/ha). Difference between lowest and highest fresh matter yield is 0.18t/ha.

Table 37. Farm mean fresh matter yield in t/ha

farm	n	fresh matter, t/ha LSMEAN	stderr.
1	7	5.44	± 0.10
2	8	5.41	± 0.07
3	8	5.29	± 0.07
4	7	5.29	± 0.10
5	8	5.47	± 0.07
6	8	5.45	± 0.07
7	8	5.47	± 0.07
8	8	5.38	± 0.07
9	6	5.38	± 0.10
10	6	5.29	± 0.10
all		5.39	

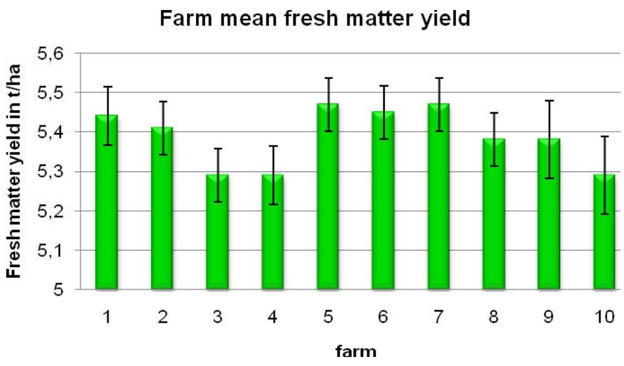

Fig. 55 Farm mean fresh matter yield in t/ha

Fixed effect breed does have a significant influence on fresh matter yield (Pr > F = 0.0241) (Table 38, Fig. 56). Significant difference is indicated by superscripts. Mean breed fresh matter yields are 5.33t/ha (farm) for Ankole pastures and 5.44t/ha for crossbred pastures. Difference between breeds is 0.11t/ha fresh matter. Fresh matter yield is significantly higher on crossbred pastures.

Table 38. Breed mean fresh matter yield in t/ha

breed	n	fresh matter, t/ha LSMEAN	stderr.
Ankole	39	5.33^{a}	± 0.03
crossbred	36	5.44^{b}	± 0.03

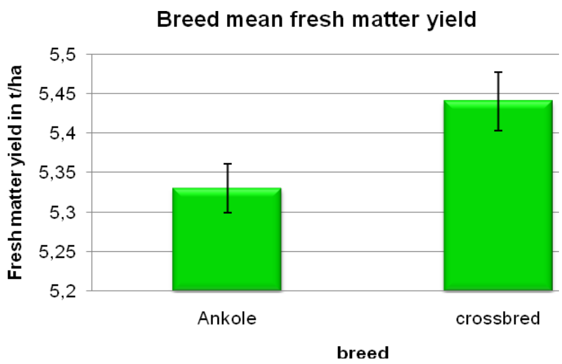

Fig. 56 Breed mean fresh matter yield in t/ha

Fixed effect season does have a significant influence on fresh matter yield (Pr > F = 0.0417). Significant difference is indicated by superscripts (Table 39, Fig. 57). Mean fresh matter yield for samples collected during late dry season is 5.33t/ha. Mean fresh matter yield for samples collected during early wet season is 5.44t/ha. The difference between samples from different seasons is 0.11t/ha.

Fresh matter yield was significantly higher for samples collected during early wet season. Mean pasture fresh matter yields range from 5.07t/ha (farm 3, Ankole pasture) to 5.58t/ha (farm 5, Ankole pasture) (mean: 5.39t/ha, median: 5.39t/ha).

Difference between highest and lowest fresh matter yield is 0.51t/ha. On Ankole pastures fresh matter yields range from 5.07t/ha (farm 3) to 5.58t/ha (farm 5) (mean: 5.32t/ha, median: 5.32t/ha).

On crossbred pastures fresh matter yields range from 5.33t/ha (farm 10) to 5.56t/ha (farm 7) (mean: 5.44t/ha, median: 5.44t/ha). Pasture mean fresh matter yields are higher on crossbred pastures.

Table 39. Season mean fresh matter yield in t/ha

season	n	fresh matter, t/ha LSMEAN	stderr.
late dry	38	5.33[a]	± 0.03
early wet	36	5.44[b]	± 0.03

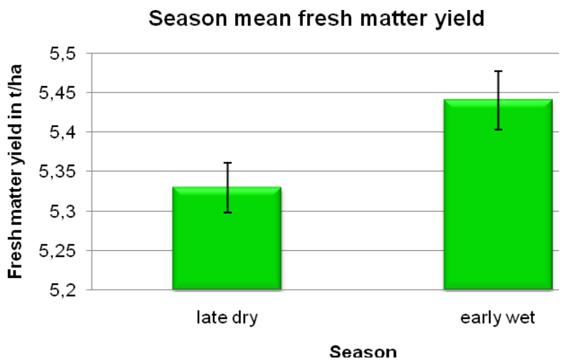

Fig. 57 Season mean fresh matter yield in t/ha

Interaction between farm and breed does not have a significant influence on fresh matter yield (Pr > F = 0.0820), but there is a statistical tendency (Table 40, Fig. 58).

Table 40. Pasture mean fresh matter yield in t/ha

	Ankole (n = 39)		**crossbred** (n = 35)	
farm	**fresh matter/ha, t LSMEAN**	**sterr**	**fresh matter/ha, t LSMEAN**	**stderr**
1	5.33	± 0.11	5.55	± 0.10
2	5.31	± 0.10	5.50	± 0.10
3	5.07	± 0.10	5.50	± 0.10
4	5.21	± 0.10	5.38	± 0.11
5	5.58	± 0.10	5.36	± 0.10
6	5.52	± 0.10	5.39	± 0.10
7	5.39	± 0.10	5.56	± 0.10
8	5.26	± 0.10	5.50	± 0.10
9	5.39	± 0.10	5.37	± 0.17
10	5.24	± 0.10	5.33	± 0.17

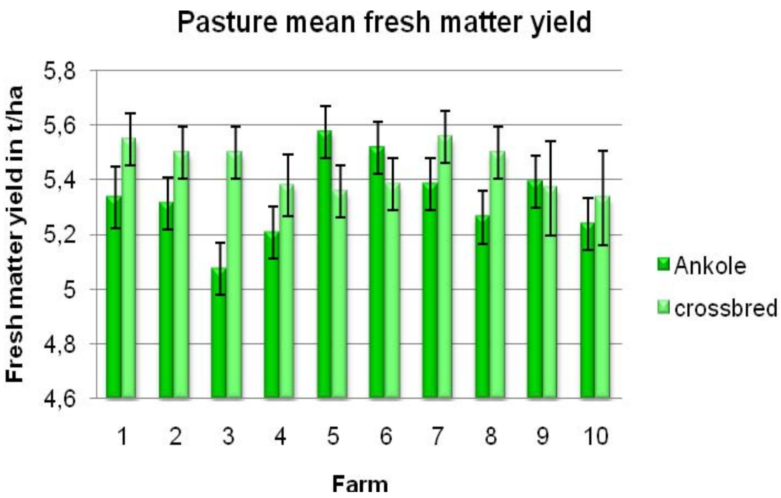

Fig. 58 Pasture mean fresh matter yield in t/ha

Interaction between farm and season does not have a significant effect on fresh matter yield (Pr > F = 0.0506), but a strong statistical tendency (Table 41,Fig. 59). Mean seasonal farm fresh matter yields range from 5.17t/ha (farms 1 and 3, late dry season) to 5.71t/ha (farm 1, early wet season) (mean: 5.39t/ha, median: 5.37t/ha).

Difference between highest and lowest mean seasonal farm fresh matter yield is 0.54t/ha. During late dry season mean seasonal fresh matter contents range from 5.17t/ha (farms 1 and 3) to 5.55t/ha (farm) (mean: 5.33t/ha, median: 5.31t/ha). During early wet season mean seasonal fresh matter yields range from 5.30t/ha (farm 10) to 5.71t/ha (farm 1) (mean: 5.44t/ha, median: 5.39t/ha).

Mean seasonal farm fresh matter yields are higher for samples collected during early wet season.

Table 41. Seasonal farm mean fresh matter yield in t/ha

	late dry (n=38)		early wet (n=36)	
farm	**fresh matter/ha, t LSMEAN**	**stderr.**	**fresh matter/ha, t LSMEAN**	**stderr.**
1	5.17	± 0.11	5.71	± 0.10
2	5.45	± 0.10	5.36	± 0.10
3	5.17	± 0.10	5.40	± 0.10
4	5.24	± 0.11	5.34	± 0.10
5	5.55	± 0.10	5.38	± 0.10
6	5.35	± 0.10	5.55	± 0.10
7	5.48	± 0.10	5.46	± 0.10
8	5.40	± 0.10	5.36	± 0.10
9	5.26	± 0.10	5.50	± 0.17
10	5.28	± 0.10	5.30	± 0.17

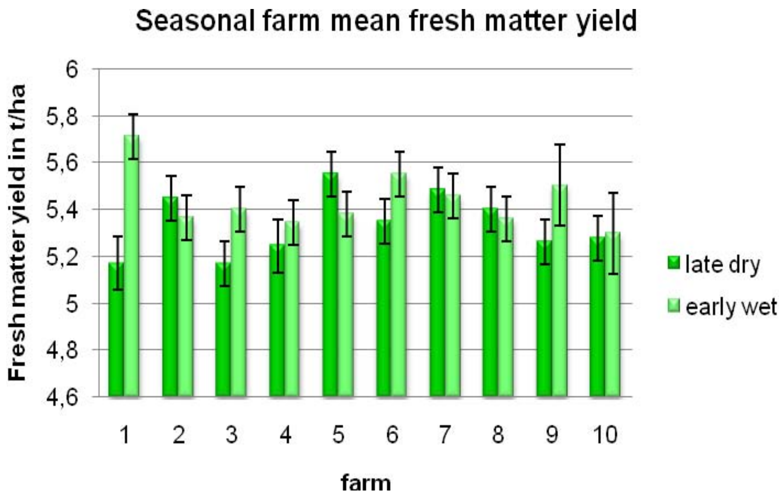

Fig. 59 Seasonal farm mean fresh matter yield in t/ha

There is no significant influence of interaction between breed and season (Pr > F = 0.5027) on fresh matter yield (Table 42, Fig. 60). Mean seasonal breed fresh matter yields range from 5.26t/ha (late dry season, Ankole) to 5.48t/ha (early wet season, crossbred). Late dry season fresh matter yields are 5.26t/ha for Ankole and 5.41t/ha for crossbred pastures. Early wet season fresh matter yields are 5.40t/ha for Ankole and 5.48t/ha for crossbred pastures. Mean values of both seasons are lower for samples from Ankole pastures. Mean values of both breeds are lower for samples collected during late dry season.

Table 42. Seasonal breed mean fresh matter yield in t/ha

breed	season	n	fresh matter/ha, t LSMEAN	stderr.
Ankole	late dry	19	5.26	± 0.04
Ankole	early wet	20	5.40	± 0.04
crossbred	late dry	19	5.41	± 0.04
crossbred	early wet	16	5.48	± 0.06

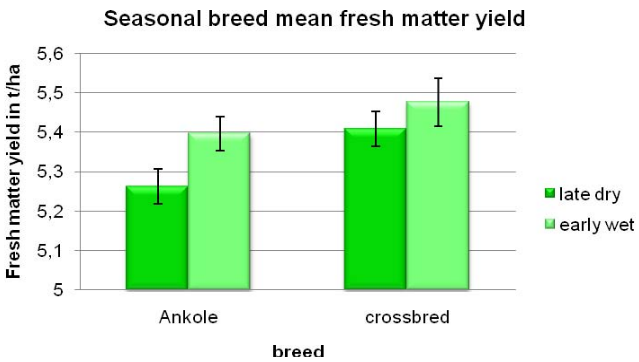

Fig. 60 Seasonal breed mean fresh matter yield in t/ha

4.4.2.2. Dry matter yield

Statistical model for analysis of fresh matter yield in t/ha has an R-Square of 0.76. Coefficient of variation is 13.90. Square root MSE is 0.28. Pr > F of the model is <.0001. 2.04t/ha was calculated to be overall LSMEAN for all samples.

Fixed effect farm has a highly significant influence on dry matter yield (Pr > F = <.0001). Significantly different farm means are indicated by superscripts (Table 9, Fig. 61). Mean farm dry matter yields range from 1.63t/ha (farm 3) to 2.49t/ha (farm) (mean: 2.05t/ha, median: 2.00 t/ha). Difference between lowest and highest dry matter yield is 0.86t/ha.

Table 43. Farm mean dry matter yield in t/ha

farm	n	dry matter, t/ha LSMEANS	stderr.
1	7	2.49^{acef}	± 0.11
2	8	2.25^{acf}	± 0.10
3	8	1.63^{acf}	± 0.10
4	7	1.78^{acf}	± 0.11
5	8	2.01^{ac}	± 0.10
6	8	1.88^{ac}	± 0.10
7	8	1.91^{bc}	± 0.10
8	8	2.23^{bc}	± 0.10
9	6	1.99^{bc}	± 0.15
10	6	2.28^{bd}	± 0.15
all		2.04	

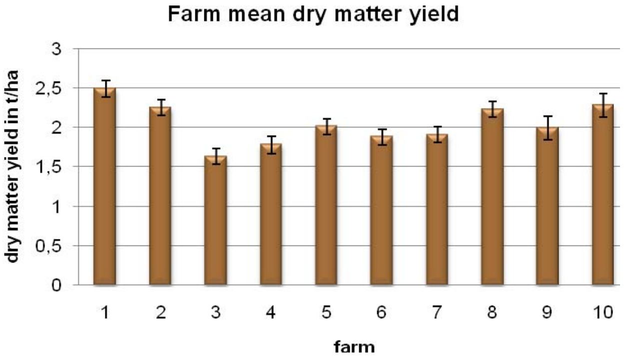

Fig. 61 Farm mean dry matter yield in t/ha

Fixed effect breed does have a significant influence on dry matter yield (Pr > F = 0.0198). Significant difference is indicated by superscripts (Table 44, Fig. 62). Mean breed dry matter yields are 1.96t/ha for Ankole and 2.13t/ha for crossbred pastures. Difference between breeds is 0.17t/ha dry matter. Dry matter yield is significantly higher on crossbred pastures.

Table 44. Breed mean dry matter yield in t/ha

breed	n	dry matter, t/ha LSMEANS	stderr.
Ankole	39	1.96^{a}	± 0.05
crossbred	36	2.13^{b}	± 0.10

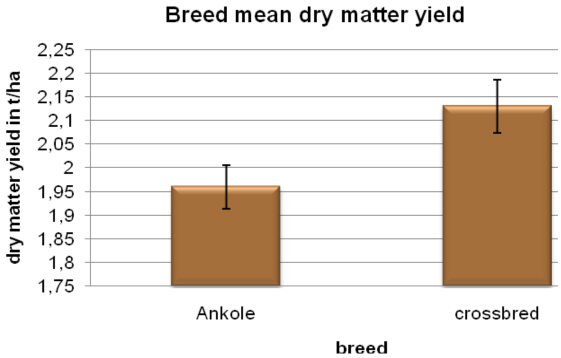

Fig. 62 Breed mean dry matter yield in t/ha

Table 45. Season mean dry matter yield in t/ha

season	n	dry matter, t/ha LSMEANS	stderr.
late dry	38	1.97	± 0.05
early wet	36	2.12	± 0.10

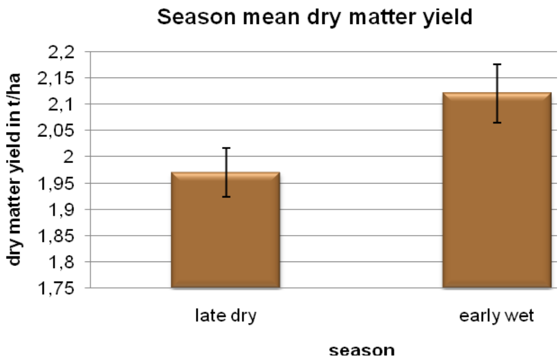

Fig. 63 Breed mean dry matter yield in t/ha

Fixed effect season does not have a significant influence on dry matter yield (Pr > F = 0.0556), but shows a statistical tendency (Table 45, Fig. 38). Mean dry matter yield for samples collected during the late dry season is 1.97t/ha. Mean dry matter yield for samples collected during early wet season is 2.12t/ha. Difference between samples from different seasons is 0.17t/ha. Dry matter yield is higher during early wet season.

Interaction between farm and breed does have a highly significant influence on dry matter yield (Pr > F = <.0001). Where pastures of a single farm are significantly different, it is indicated by superscripts "a" and "b" for respective pastures (Table 46, Fig. 64). Mean pasture dry matter yields range from 1.25t/ha (farm 3, Ankole pasture) to 2.58t/ha (farm 1, Ankole pasture) (mean: 2.05t/ha, median: 2.02t/ha). Difference between highest and lowest dry matter yield is 1.33t/ha. On Ankole pastures dry matter yields range from 1.25t/ha (farm 3) to 2.58t/ha (farm 1) (mean: 1.96t/ha, median: 1.93t/ha). On crossbred pastures dry matter yields range from 1.78t/ha (farm 4) to 2.57t/ha (farm 5) (mean: 2.13t/ha, median: 2.04t/ha). Pasture mean dry matter yields are higher on crossbred pastures. Mean and median values of Ankole pastures are smaller than mean and median values of all pastures. Ankole and crossbred pastures on farms 3 and 5 show a significant difference in dry matter yield.

Table 46. Pasture mean dry matter yield in t/ha

	Ankole (n = 39)		**crossbred** (n = 35)	
farm	**dry matter, t/ha LSMEANS**	**stderr.**	**dry matter, t/ha LSMEANS**	**stderr.**
1	2.58	± 0.17	2.41	± 0.14
2	2.39	± 0.14	2.10	± 0.14
3	1.25[a]	± 0.14	2.01[b]	± 0.14
4	1.78	± 0.14	1.78	± 0.17
5	1.45[a]	± 0.14	2.57[b]	± 0.14
6	1.90	± 0.14	1.86	± 0.14
7	1.78	± 0.14	2.05	± 0.14
8	1.95	± 0.14	2.52	± 0.14
9	1.97	± 0.14	2.02	± 0.26
10	2.55	± 0.14	2.02	± 0.26

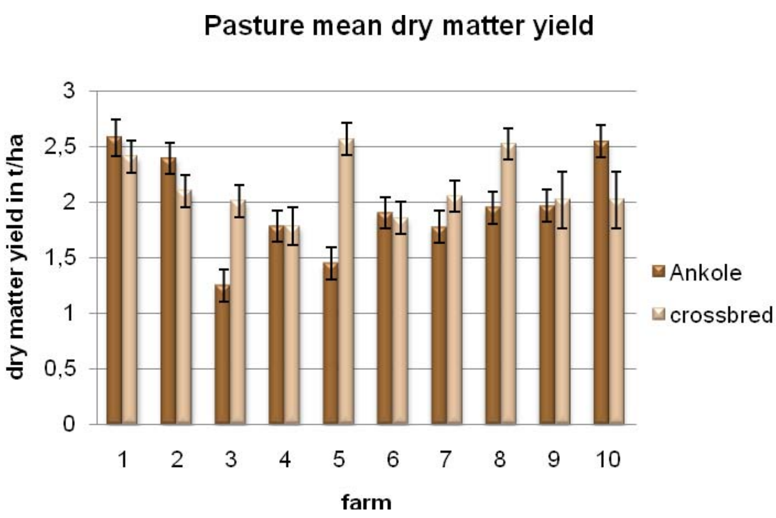

Fig. 64 Pasture mean dry matter yield in t/ha

Interaction between farm and season does not have a significant effect on dry matter yield (Pr > F = 0.2088) (Table 47, Fig. 65). Mean seasonal farm dry matter yields range from 1.20t/ha (farm 3, early wet season) to 2.59t/ha (farm 1, late dry season) (mean: 2.01t/ha, median: 2.00t/ha). Difference between highest and lowest mean seasonal farm dry matter yield is 1.39t/ha. Highest dry matter yield is more than twice as much as lowest. During late dry season mean seasonal dry matter contents range from 1.62t/ha (farm 4) to 2.59t/ha (farm 1) (mean: 1.97t/ha, median: 1.97t/ha). During early wet season mean seasonal dry matter yields range from 1.20t/ha (farm 6) to 2.51t/ha (farm 2) (mean: 2.04t/ha, median: 2.05t/ha). Mean seasonal farm dry matter yields are higher for early wet season.

Table 47. Seasonal farm mean dry matter yield in t/ha

farm	**late dry** (n= 38) dry matter, t/ha LSMEANS	stderr	**early wet** (n = 36) dry matter, t/ha LSMEANS	stderr
1	2.59	± 0.17	2.40	± 0.14
2	1.99	± 0.14	2.51	± 0.14
3	1.73	± 0.14	1.53	± 0.14
4	1.62	± 0.17	1.94	± 0.14
5	1.94	± 0.14	2.07	± 0.14
6	1.76	± 0.14	1.20	± 0.14
7	1.81	± 0.14	2.02	± 0.14
8	2.00	± 0.14	2.47	± 0.14
9	2.02	± 0.14	1.96	± 0.26
10	2.28	± 0.14	2.28	± 0.26

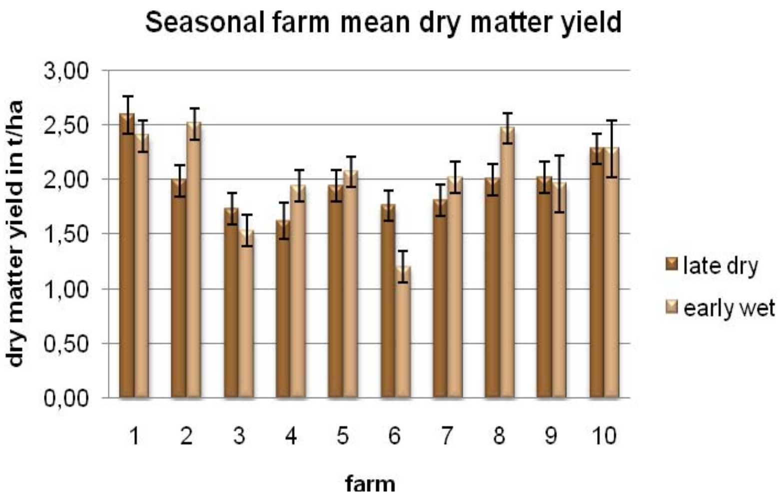

Fig. 65 Seasonal farm mean dry matter yield in t/ha

There is no significant influence of interaction between breed and season (Pr > F = 0.5336) on dry matter yield (Table 48, Fig. 66). Mean seasonal breed dry matter yields range from 1.91t/ha (late dry season, Ankole) to 2.23t/ha (early wet season, crossbred). Late dry season dry matter yields are 1.91t/ha for Ankole, 2.04t/ha for crossbred pastures. Early wet season dry matter yields are 2.01t/ha for Ankole, 2.23t/ha for crossbred pastures. Mean values of both seasons are lower for samples from Ankole pastures. Mean values for both breeds are lower during late dry season.

Table 48. Seasonal breed mean dry matter yield in t/ha

breed	season	n	dry matter, t/ha LSMEANS	stderr.
Ankole	late dry	19	1.91	± 0.07
Ankole	early wet	20	2.01	± 0.06
crossbred	late dry	19	2.04	± 0.07
crossbred	early wet	16	2.23	± 0.09

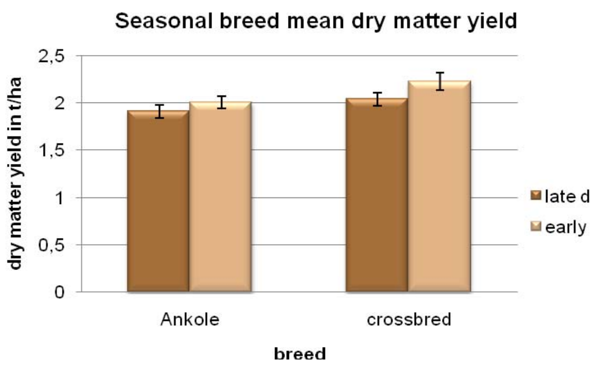

Fig. 66 Seasonal breed mean dry matter yield in t/ha

4.4.2.3. Dry matter content in percent

Statistical model for analysis of dry matter content in percent has a R-Square of 0.76. 75 values were used for statistical analysis. Coefficient of variation is 14.14. Square root MSE is 5.34. Pr > F of the model is <.0001. 37.79% was calculated to be overall LSMEAN for all samples.

Fixed effect farm has a highly significant influence on dry matter content (Pr > F = <.0001). Significantly different farms values are indicated by superscripts (Table 49, Fig. 67). Mean farm dry matter contents range from 30.75% (farm 3) to 46.07% (farm 1) (mean: 37.79%, median: 37.03%). Difference between lowest and highest dry matter content is 15.32%.

Table 49. Farm mean dry matter in %

farm	n	dry matter % LSMEANS (n=75)	stderr.
1	7	46.07^{aceg}	± 2.07
2	8	41.67^{actg}	± 1.89
3	8	30.75^{bdfh}	± 1.89
4	8	33.15^{bcfh}	± 1.89
5	8	36.90^{acfh}	± 1.89
6	8	34.40^{bcfh}	± 1.89
7	8	34.97^{bcfh}	± 1.89
8	8	41.48^{actg}	± 1.89
9	6	37.15^{acfh}	± 2.76
10	6	43.30^{actg}	± 2.76
all		37.79	

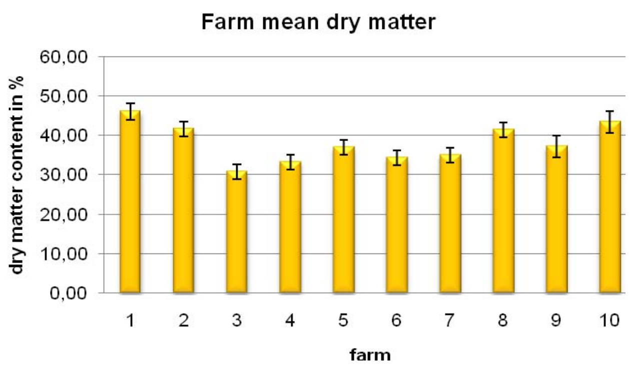

Fig. 67 Farm mean dry matter content in %

Fixed effect breed does not have a significant influence on dry matter content, but shows a statistical tendency. (Pr > F = 0.0947) (Table 50, Fig. 68). Mean dry matter content for samples from Ankole pastures is 36.84%. Mean dry matter content for samples from crossbred pastures is 39.13%. Difference between breeds is 2.29%. Mean dry matter content is higher on crossbred pastures.

breed	n	dry matter% LSMEANS (n=75)	stderr.
Ankole	39	36.84	± 0.86
cross bred	36	39.13	± 1.04

Table 50. Breed mean dry matter contents in %

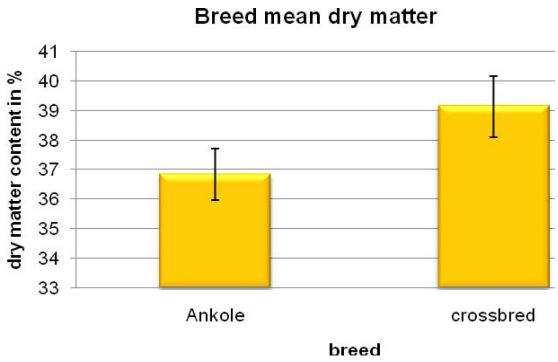

Fig. 68 Breed mean dry matter content in %

Fixed effect season does not have a significant influence on dry matter content (Pr > F = 0.1342) (Table 51, Fig. 69). Mean dry matter content for samples collected during late dry season is 36.96%. Mean dry matter content for samples collected during early wet season is 39.01%. Difference between samples from different seasons is 0.95%.

Table 51. Season mean dry matter content in %

season	n	dry matter% LSMEANS (n=75)	stderr.
late dry	39	36.96	± 0.86
early wet	36	39.01	± 1.04

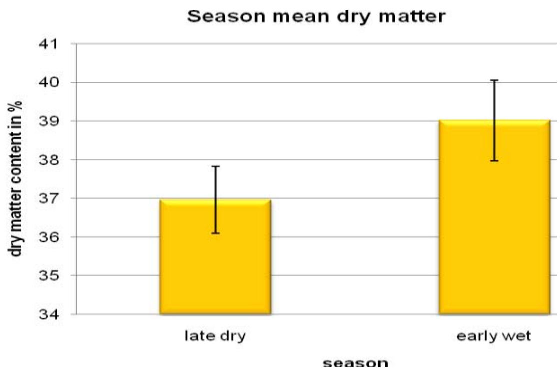

Fig. 69 Season mean dry matter content in %

Interaction between farm and breed does have a highly significant influence on dry matter content (Pr > F = <.0001). Where pastures of a single farm are significantly different, this is indicated by superscripts “a” and “b” for the respective farm (Table 52, Fig. 70).

Mean pasture dry matter contents range from 24.85% (farm 3, Ankole pasture) to 48.65% (farm 10, Ankole pasture) (mean: 37.98%, median: 38.00%). Difference between highest and lowest dry matter content is 23.80%.

On Ankole pastures dry matter contents range from 24.85% (farm 3) to 48.65% (farm 10) (mean: 36.84%, median: 35.51%). On crossbred pastures dry matter contents range from 32.00% (farm 4) to 47.84% (farm 5) (mean: 39.13%, median: 37.85%).

Pasture mean dry matter content is higher on crossbred pastures. Ankole and crossbred pastures on farm 5 show a significant difference in dry matter content.

Table 52. Pasture mean dry matter content in %

	Ankole (n = 39)		**crossbred** (n = 36)	
farm	**dry matter% LSMEANS**	**stderr**	**dry matter% LSMEANS**	**stderr.**
1	48.58	± 3.17	43.56	± 2.67
2	44.99	± 2.67	38.35	± 2.67
3	24.85	± 2.67	36.64	± 2.67
4	34.29	± 2.67	32.00	± 2.67
5	25.96[a]	± 2.67[b]	47.84	± 2.67
6	34.47	± 2.67	34.34	± 2.67
7	32.98	± 2.67	36.96	± 2.67
8	37.04	± 2.67	45.93	± 2.67
9	36.55	± 2.67	37.74	± 4.82
10	48.65	± 2.67	37.95	± 4.82

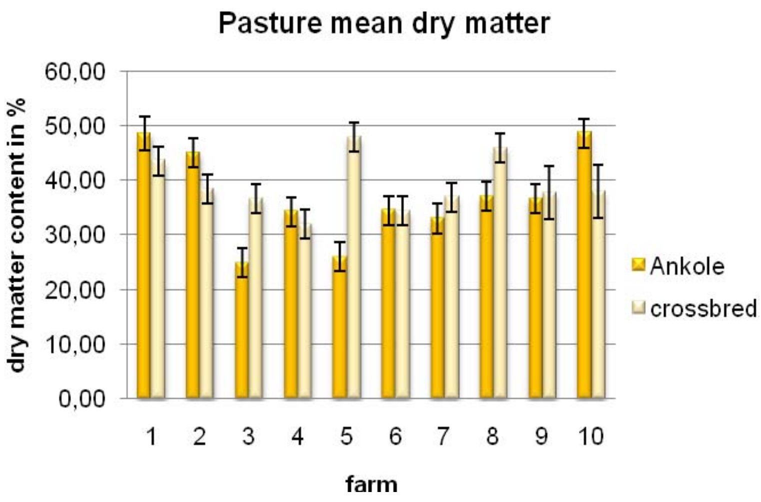

Fig. 70 Pasture mean dry matter content in %

Interaction between farm and season does have a significant effect (Pr > F = 0.0416) (Table 53, Fig. 71).

Table 53. Mean seasonal farm dry matter contents in %

	late dry (n = 39)		**early wet** (n = 36)	
farm	**dry matter% LSMEANS**	**stderr.**	**dry matter% LSMEANS**	**stderr.**
1	50.14	± 3.17	42.00	± 2.67
2	36.67	± 2.67	46.67	± 2.67
3	33.14	± 2.67	28.36	± 2.67
4	30.02	± 2.67	36.27	± 2.67
5	34.98	± 2.67	38.82	± 2.67
6	32.79	± 2.67	36.02	± 2.67
7	33.02	± 2.67	36.93	± 2.67
8	36.98	± 2.67	46.00	± 2.67
9	38.52	± 2.67	35.77	± 4.82
10	43.35	± 2.67	43.25	± 4.82

Mean seasonal farm dry matter contents range from 28.36% (farm 3, early wet season) to 50.14% (farm 1, late dry season) (mean: 37.99%, median: 36.80%). Difference between highest and lowest mean seasonal farm dry matter content is 21.78%. During late dry season dry matter contents per farm range from 30.02% (farm 4) to 50.14% (farm 1) (mean: 36.96%, median: 35.82%). During early wet season dry matter contents per farm range from 28.36% (farm 3) to 46.67% (farm 2) (mean: 39.01%, median: 37.88%).

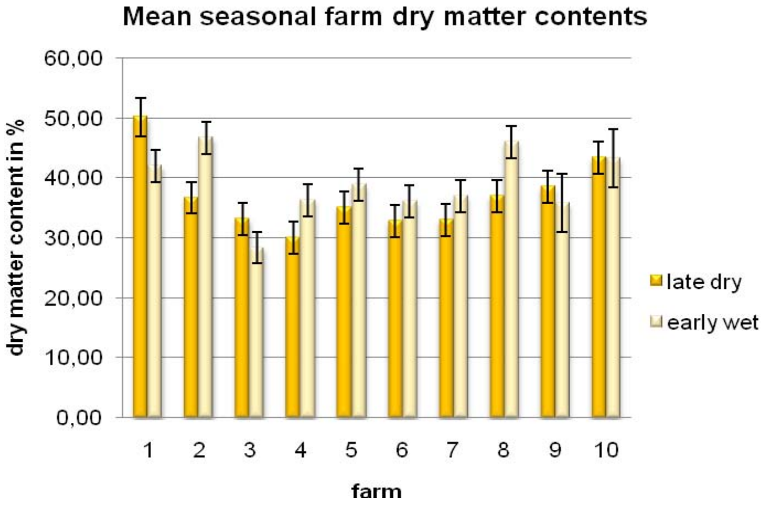

Fig. 71 Mean seasonal farm dry matter contents in %

Mean seasonal farm dry matter contents are higher for early wet season. Ankole and crossbred pastures show no significant difference in dry matter percent. Significantly different pastures must be from different farms and are therefore not indicated.

Table 54. Mean seasonal breed dry matter content in %

breed	season	n	dry matter% LSMEANS (n=75)	stderr.
Ankole	late dry	19	36.45	1.24
Ankole	early wet	20	37.23	1.20
cross bred	late dry	20	37.47	1.20
cross bred	early wet	16	40.79	1.69

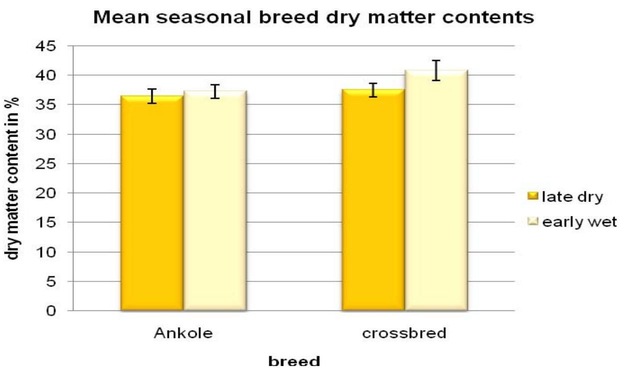

Fig. 72. Mean seasonal breed dry matter content in %

There is no significant influence of interaction between breed and season (Pr > F = 0.3531) on dry matter content (Table 54, Fig. 72). Mean seasonal breed dry matter contents range from 36.45% (late dry season, Ankole) to 40.79% (early wet season, crossbred). Late dry season dry matter content is 36.45% for Ankole and 37.47% for crossbred pastures. Early wet season dry matter contents are 37.23% for Ankole and 40.79% for crossbred pastures. Mean values of both seasons are lower for samples from Ankole pastures than from crossbred pastures.

4.5. Results of nutrient analyses

For statistical analysis of gross energy content 8 samples, collected on farm 1, were used (4.5.1). LSMEANS were calculated for fixed effects breed, season and for effect of interaction between breed and season.

For statistical analyses of crude protein content (4.5.2), neutral detergent fibre content (4.5.3) and phosphorus content (4.5.4) 76 samples could be used. For statistical analyses of calcium content (4.5.5) 75 samples could be used.

4.5.1. Gross energy content

The model for statistical analysis of gross energy content has a R-Square of 0.29 and determined LSMEAN gross energy content of 3.97 kcal/g for all pastures. Coefficient of variation is 4.99. Square root MSE is 0.20. Pr > F of the model is 0.67.

Fixed effect breed does not have a significant influence on gross energy content (Pr > F = 0.6906) (

Table 55, Fig. 73). Breed mean gross energy contents are 4.00 kcal/g for samples collected on Ankole and 3.94 kcal/g for samples collected on crossbred pastures. Difference is 0.06kcal/g.

Table 55. Breed mean gross energy contents in kcal/g

breed	n	GE kcal/g LSMEANS	stderr.
Ankole	4	4.00	± 0.10
cross bred	4	3.94	± 0.10

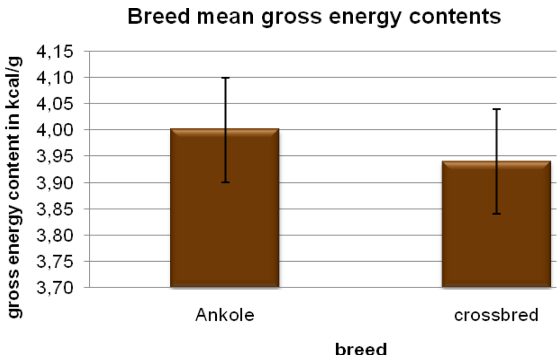

Fig. 73 Breed mean gross energy contents in kcal/g

Fixed effect season does not have a significant influence on gross energy content (Pr > F = 0.9813) (Table 56, Fig. 74). Season mean gross energy contents are the same for both seasons (3.98 kcal/g).

Table 56. Season mean gross energy contents in kcal/g

season	n	GE kcal/g LSMEANS	stderr.
late dry	4	3.98	± 0.10
early wet	4	3.98	± 0.10

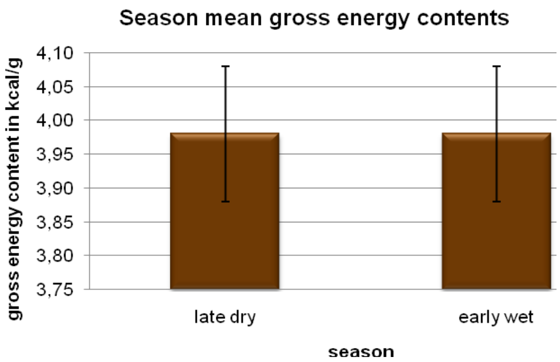

Fig. 74 Season mean gross energy contents in kcal/g

There is no significant influence of interaction between season and breed on gross energy content (Pr > F =0.2912) (Table 57, Fig. 75). Mean gross energy contents for samples collected during late dry season are 4.09 kcal/g on Ankole and 3.86 kcal/g on crossbred pastures. Mean gross energy contents for samples collected during early wet season are 3.92 kcal/g for Ankole and 4.03 kcal/g for crossbred pastures. Gross energy content during late dry season was higher for Ankole pastures. Gross energy content during early wet season was higher for crossbred pastures.

Table 57. Seasonal breed mean gross energy contents in kcal/g

breed	season	n	GE kcal/g LSMEANS	stderr.
Ankole	later dry	2	4.09	± 0.14
Ankole	early wet	2	3.92	± 0.14
cross bred	late dry	2	3.86	± 0.14
cross bred	early wet	2	4.03	± 0.14

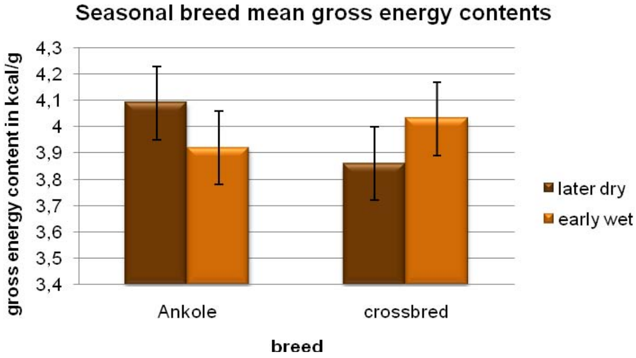

Fig. 75 Seasonal breed mean gross energy contents in kcal/g

4.5.2. Crude protein content

The model for statistical analysis of crude protein content in percent has a R-Square of 0.44 and determined an overall LSMEAN crude protein content of 6.71%. Coefficient of variation is 25.89. Square root MSE is 1.74. Pr > F of the model is 0.0205.

Factor farm (Pr > F = 0.0204) has a significant influence on protein content. Significantly different values are indicated by superscripts (Table 58, Fig. 76). Crude protein contents range from 5.52% (farm 9) to 8.51% (farm 3). Significant differences in protein content do exists between farm 3 and farm 9.

Table 58. Farm mean crude protein contents in %

farm	n	cp % LSMEANS	stderr.
1	7	5.56	± 0.66
2	8	6.29	± 0.61
3	7	8.51 [a]	± 0.66
4	7	7.40	± 0.66
5	8	7.50	± 0.61
6	8	6.72	± 0.61
7	7	7.85	± 0.66
8	8	6.43	± 0.61
9	8	5.52 [b]	± 0.61
10	8	5.97	± 0.61
all		6.71	

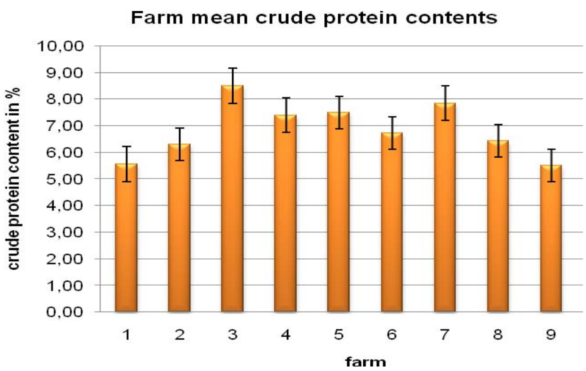

Fig. 76 Farm mean crude protein contents in %

Effect breed (Pr > F = 0.0217) has a significant influence on crude protein content. Significantly different values are indicated by superscripts (

Table **59**, Fig. 77).

Mean crude protein content of samples from Ankole pastures is 7.25%. Mean crude protein content of samples from crossbred pastures is 6.30% Difference between crude protein contents of pastures stocked with different breeds is 0.95%.

Farm 9 and farm 3 have significantly different crude protein contents.

Table 59. Breed mean crude protein contents in %

breed	n	cp % LSMEANS	stderr.
Ankole	38	7.25[a]	0.28
crossbred	38	6.30[b]	0.28

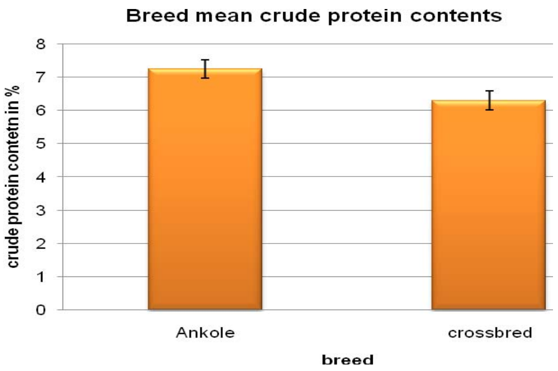

Fig. 77 Breed mean crude protein contents in %

Season does not have a significant influence on crude protein content (Pr > F = 0.3710) (

Table 60, Fig. 78). Mean crude protein content during late dry season is 6.96%. Mean crude protein content during early wet season is 6.59%. Difference of protein content in samples collected during different seasons is 0.40%.

Table 60. Season mean crude protein contents in %

season	n	cp % LSMEANS	stderr.
late dry	37	6.96	± 0.29
early wet	39	6.59	± 0.28

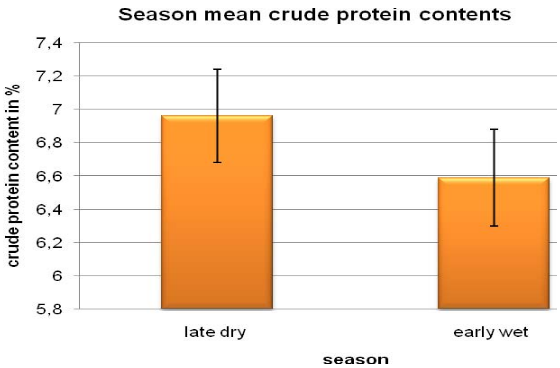

Fig. 78 Season mean crude protein contents in %

There is no significant effect of interaction between farm and breed on crude protein content (Pr > F = 0.0932) (Table 61, Fig. 79).

Table 61. Pasture mean crude protein contents in %

	Ankole			crossbred		
farm	n	cp % LSMEANS	stderr.	n	cp % LSMEANS	stderr.
1	3	5.47	± 1.01	4	5.65	± 0.87
2	4	6.75	± 0.87	4	5.83	± 0.87
3	3	10.56	± 1.01	4	6.47	± 0.87
4	4	7.35	± 0.87	3	7.49	± 1.01
5	4	9.16	± 0.87	4	5.85	± 0.87
6	4	7.45	± 0.87	4	5.99	± 0.87
7	4	7.05	± 0.87	3	8.66	± 1.01
8	4	7.20	± 0.87	4	5.66	± 0.87
9	4	5.70	± 0.87	4	5.33	± 0.87
10	4	5.84	± 0.87	4	6.11	± 0.87

There is statistical tendency towards an effect of interaction between farm and breed. Pasture mean crude protein contents range from 5.33% (farm 9, crossbred pasture) to

10.56% (farm 3, Ankole pasture) (mean: 6.78%, median: 6.29%). Crude protein contents for Ankole pastures range from 5.47% (farm 1) to 10.56% (farm 3) (mean: 7.25%, median: 7.13%). Crude protein contents for crossbred pastures range from 5.33% (farm 9) to 8.66% (farm 7) (mean: 6.30%, median: 5,92%). Pasture mean crude protein contents were higher for Ankole pastures.

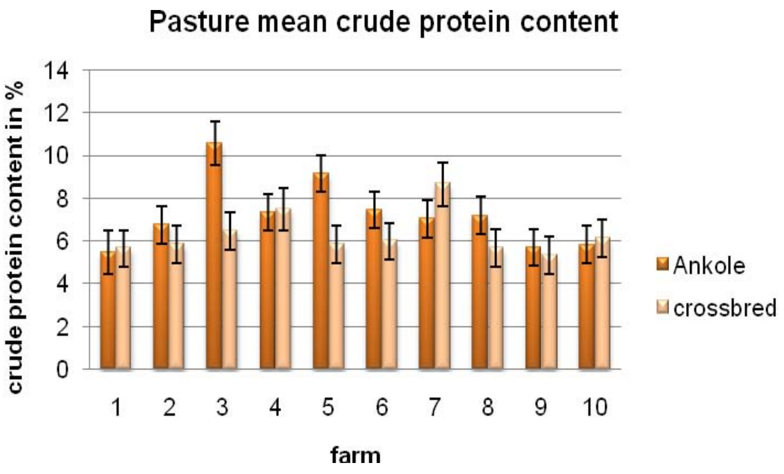

Fig. 79 Pasture mean crude protein contents in %

There is no significant influence of interaction between season and breed (Pr > F = 0.8494) on crude protein content (Table 62, Fig. 80). Seasonal breed mean crude protein contents range from 6.08% (crossbred, early wet season) to 7.39% (Ankole, late dry season). Samples collected during late dry season have higher mean crude protein contents for both breeds than samples collected during early wet season. Difference in crude protein contents between seasons is larger for samples from crossbred pastures. In both seasons, mean crude protein contents are higher for samples collected on Ankole pastures.

Table 62. Seasonal breed mean crude protein content in %

breed	season	n	cp % LSMEANS	stderr.
Ankole	late dry	18	7.39	± 0.42
Ankole	early wet	20	7.11	± 0.39
cross bred	late dry	19	6.52	± 0.40
cross bred	early wet	19	6.08	± 0.40

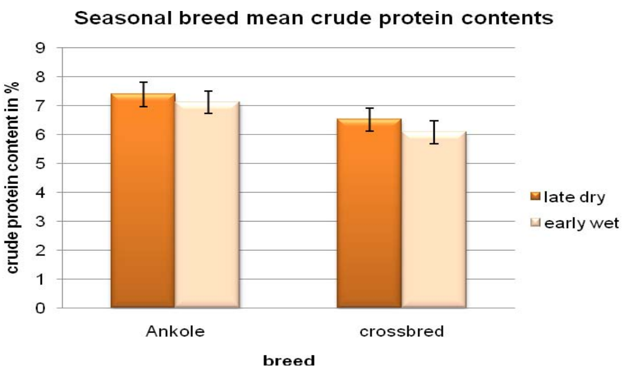

Fig. 80 Seasonal breed mean crude protein content in %

4.5.3. Neutral detergent fibre content

The model for statistical analysis of neutral detergent fibre content has a R-Square of 0.32 and determined an overall LSMEAN phosphorus content of 71.36%. Coefficient of variation is 15.30. Square root MSE is 10.92. Pr > F of the model is 0.28.

Fixed effect farm does not have a significant influence on neutral detergent fibre content (Pr > F =0.4334) (Table 63, Fig. 81).

Mean ndf contents range from 68.24% (farm 3) to 81.60% (farm 5). Difference between lowest and highest ndf content is 13.39%.

Table 63. Farm mean ndf contents in %

farm	n	ndf % LSMEANS	stderr.
1	7	72.94	± 4.18
2	8	69.34	± 3.86
3	7	68.24	± 4.18
4	7	68.96	± 4.18
5	8	81.60	± 3.86
6	8	72.07	± 3.86
7	7	69.07	± 4.18
8	8	69.75	± 3.86
9	8	71.85	± 3.86
10	8	69.14	± 3.86
all		71.36	

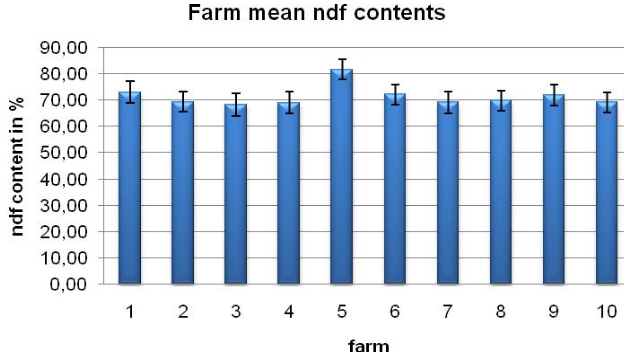

Fig. 81 Farm mean ndf contents in %

Table 64. Breed mean ndf content in %

breed	n	ndf % LSMEANS	stderr.
Ankole	38	69.77	± 1.79
cross bred	38	72.82	± 1.78

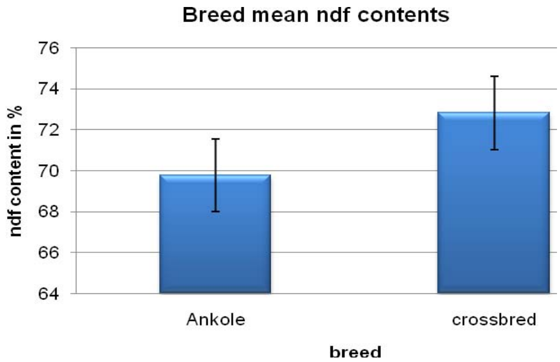

Fig. 82 Breed mean ndf contents in %

Fixed effect breed does not have a significant influence on neutral detergent fibre content (Pr > F =0.2320) (

Table 64, Fig. 82).

Mean neutral detergent fibre content on Ankole pastures is 66.77%. Mean neutral detergent fibre content on crossbred pastures is 72.92%. Difference between breeds is 6.15%. Neutral detergent fibre content is higher for samples from Ankole pastures.

Fixed effect season does not have a significant influence on neutral detergent fibre content (Pr > F = 0.1010) (Table 65, Fig. 83).

Mean neutral detergent fibre content for samples collected during late dry season is 73.40%, for samples collected during early wet season 69.19%. Difference in ndf content between seasons is 4.21%.

Table 65. Season mean ndf contents in %

Season	ndf % LSMEANS (n = 76)	stderr.
late dry	73.40	± 1.81
early wet	69.19	± 1.75

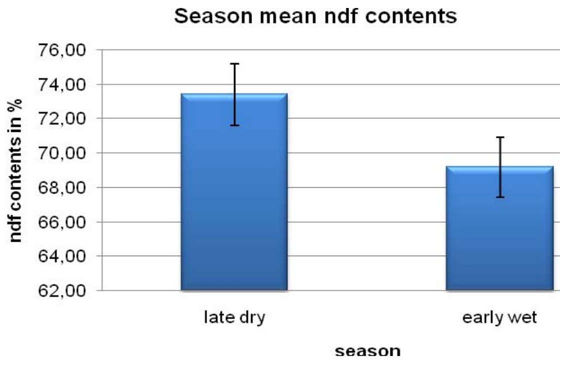

Fig. 83 Season mean ndf contents in %

There is no significant influence of interaction between season and breed (Pr > F = 0.1251) on neutral detergent fibre content (Table 66, Fig. 84). Mean ndf contents for late dry season are 69.91% for Ankole and 76.90% for crossbred pastures. Mean ndf contents for early wet season are 69.63% for Ankole and 68.74 % for crossbred pastures. Lowest ndf content has been measured during early wet season on crossbred pastures (68.74%). Highest ndf content has been measured during late dry season on crossbred pastures (76.90%).

Table 66. Seasonal breed mean ndf contents in %

breed	season	n	ndf % LSMEANS	stderr.
Ankole	late dry	18	69.91	± 2.61
Ankole	early wet	20	69.63	± 2.61
cross bred	late dry	19	76.90	± 2.52
cross bred	early wet	19	68.74	± 2.52

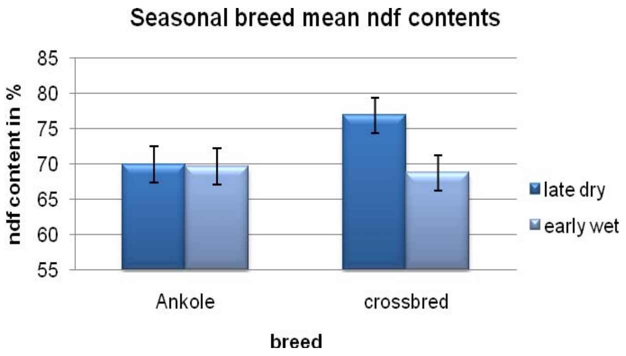

Fig. 84 Seasonal breed mean ndf contents in %

Table 67. Pasture mean ndf contents in %

farm	n	Ankole ndf % LSMEANS	stderr.	n	crossbred ndf % LSMEANS	stderr.
1	3	73.50	± 6.33	4	72.38	± 5.46
2	4	69.98	± 5.46	4	68.68	± 5.46
3	3	66.34	± 6.33	4	70.13	± 5.46
4	4	67.59	± 5.46	3	70.32	± 6.33
5	4	69.42	± 5.46	4	93.79	± 5.46
6	4	73.11	± 5.46	4	71.04	± 5.46
7	4	68.09	± 5.46	3	70.04	± 6.33
8	4	71.50	± 5.46	4	68.00	± 5.46
9	4	70.35	± 5.46	4	73.36	± 5.46
10	4	67.815	± 5.46	4	70.47	± 5.46

There is no significant influence of interaction between farm and breed (Pr > F = 0.4193) on neutral detergent fibre content (Table 67, Fig. 85). Pasture mean ndf contents range from 66.34% (Ankole pasture, farm 3) to 93.79% (crossbred pasture, farm 5) (mean: 71.30%, median: 70.23%).

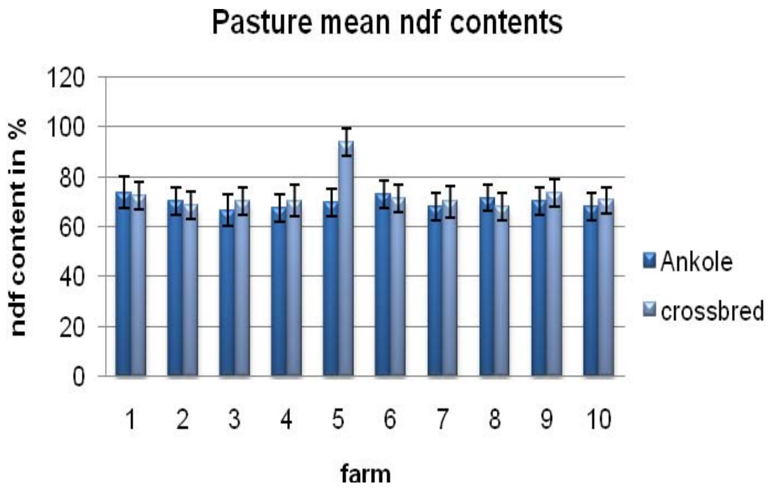

Fig. 85 Pasture mean ndf contents in %

Ndf values for Ankole pastures range from 66.34% (farm 3) to 73.50% (farm 9) (mean: 69.77%, median: 69.7%). Ndf values for crossbred pastures range from 68.00% to 93.79% (mean: 72.82%, median: 70.40%).

4.5.4. Phosphorus content

The model for statistical analysis of phosphorus content has a R-Square of 0.38 and determined overall LSMEAN phosphorus content of 0.18%. Coefficient of variation is 66.94. Square root MSE is 0.12. Pr > F of the model is 0.0952.

Fixed effect farm does not have a significant influence on phosphorus content (Pr > F = 0.0790) (Table 68, Fig. 86). Occuring There is statistical tendency towards an influence. Farm mean phosphorus contents range from 0.11% (farms 1 and 10) to 0.32% (farm 7) (mean: 0.18, median: 0.18).

Table 68. Farm mean phosphorus contents in %

farm	n	P % LSMEANS	stderr.
1	7	0.11	± 0.046
2	8	0.14	± 0.042
3	7	0.22	± 0.046
4	7	0.19	± 0.046
5	8	0.19	± 0.042
6	8	0.16	± 0.042
7	7	0.32	± 0.046
8	8	0.15	± 0.042
9	8	0.20	± 0.042
10	8	0.11	± 0.042
all		0.18	

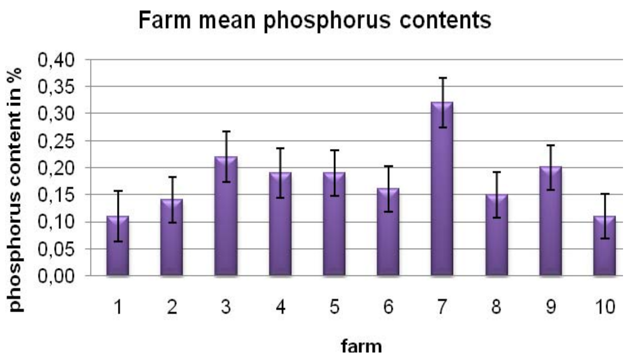

Fig. 86 Farm mean phosphorus contents in %

Fixed effect breed does not have a significant influence on phosphorus content (Pr > F =0.1148) (

Table 69, Fig. 87). Breed mean phosphorus contents are 0.20% for Ankole pastures and 0.16% crossbred pastures. Difference is 0.04%.

Table 69. Breed mean phosphorus content in %

breed	n	P % LSMEANS	stderr.
Ankole	38	0.20	± 0.020
cross bred	38	0.16	± 0.019

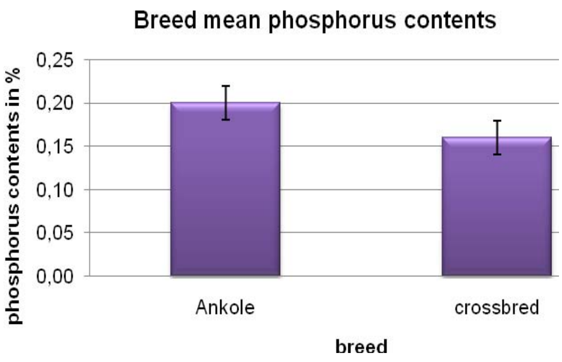

Fig. 87 Breed mean phosphorus contents in %

Fixed effect season does not have a significant influence on phosphorus content (Pr > F = 0.3520) (Table 70, Fig. 88). Season mean phosphorus contents are 0.19% for samples collected during late dry season and 0.17% for samples collected during early wet season. Phosphorus content is higher in samples collected during late dry season, but the difference between late dry and early wet season is only 0.02%.

Table 70. Season mean phosphorus contents in %

season	n	P % LSMEANS	stderr.
late dry	37	0.19	± 0.02
early wet	39	0.17	± 0.02

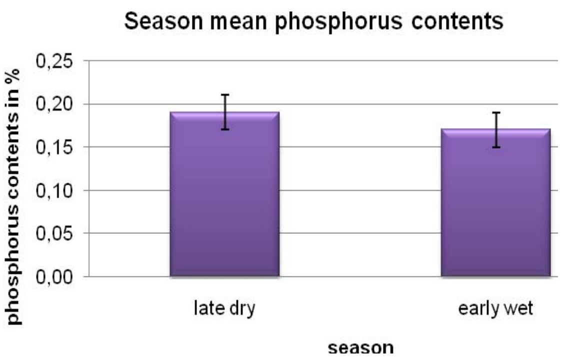

Fig. 88 Season mean phosphorus contents in %

Table 71. Pasture mean phosphorus contents in %

	Ankole			crossbred		
farm	n	P % LSMEANS	stderr.	n	P % LSMEANS	stderr.
1	3	0.09	± 0.07	4	0.12	± 0.06
2	4	0.15	± 0.06	4	0.13	± 0.06
3	3	0.22	± 0.07	4	0.22	± 0.06
4	4	0.22	± 0.06	3	0.16	± 0.07
5	4	0.25	± 0.06	4	0.13	± 0.06
6	4	0.12	± 0.06	4	0.20	± 0.06
7	4	0.41	± 0.06	3	0.23	± 0.07
8	4	0.20	± 0.06	4	0.10	± 0.06
9	4	0.27	± 0.06	4	0.12	± 0.06
10	4	0.08	± 0.06	4	0.15	± 0.06

There is no significant influence of interaction between farm and breed on phosphorus content (Pr > F = 0.3625) (Table 71, Fig. 89). Pasture mean phosphorus content ranges from 0.08% (Ankole pasture, farm 10) to 0.41% (Ankole pasture, farm 7). For Ankole pastures mean phosphorus contents range from 0.08% (farm 10) to 0.41% (farm 7) (mean:

0.20%, median: 0.21%). For crossbred pastures mean phosphorus contents range from 0.1% (farm 8) to 0.23% (farm 7) (mean: 0.16%, median: 0.14).

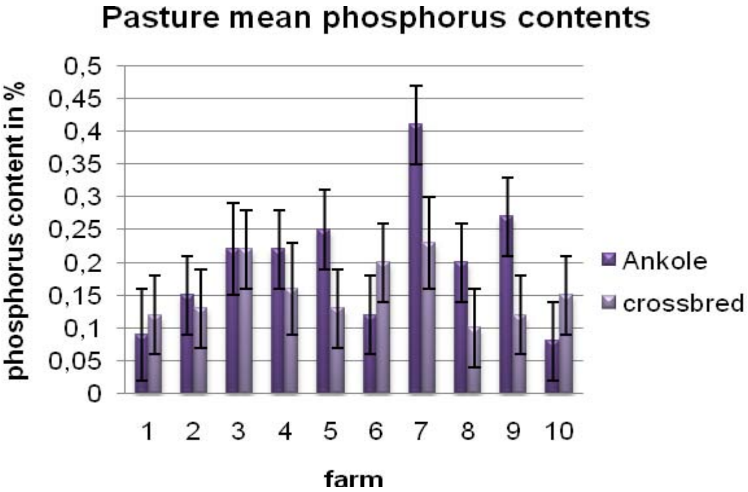

Fig. 89 Pasture mean phosphorus contents in %

There is no significant influence of interaction between season and breed on phosphorus content (Pr > F = 0.6156) (Table 72, Fig. 90). Mean phosphorus contents for samples collected during late dry season are 0.22% on Ankole and 0.16% on crossbred pastures. Mean phosphorus contents for samples collected during early wet season are 0.18% for Ankole and 0.15% for crossbred pastures. For both breeds, samples collected during late dry season had higher phosphorus contents than samples collected during early wet season. Samples from Ankole pastures have higher phosphorus contents than samples from crossbred pastures.

Table 72. Seasonal breed mean phosphorus contents in %

breed	season	n	P% LSMEANS	stderr.
Ankole	late dry	18	0.22	± 0.03
Ankole	early wet	20	0.18	± 0.03
cross bred	late dry	19	0.16	± 0.03
cross bred	early wet	19	0.15	± 0.03

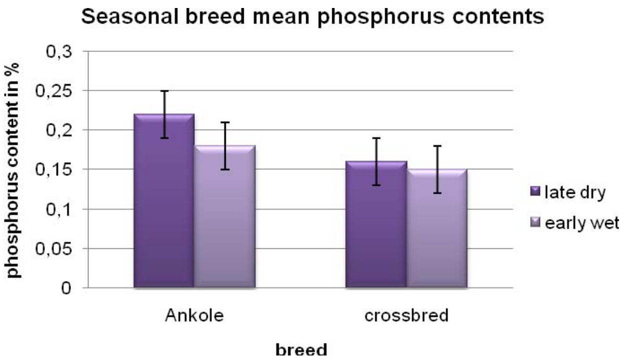

Fig. 90 Seasonal breed mean phosphorus contents in %

4.5.5. Calcium content

The model for statistical analysis of calcium content has a R-Square of 0.18 and determined overall LSMEAN calcium content of 0.085 %. Coefficient of variation is 39.63. Square root MSE is 0.03. Pr > F of the model is 0.94.

Fixed effect farm does not have a significant influence on calcium content (Pr > F = 0.8068) (Table 73, Fig. 91). Farm mean calcium contents range from 0.07% (farm 9) to 0.10% (farm

3 and farm 5) (mean: 0.09%, median: 0,09%). Difference between lowest and highest mean calcium content is 0.03%.

Table 73. Farm mean calcium contents in %

farm	n	Ca% LSMEANS	stderr.
1	7	0.08	± 0.01
2	8	0.09	± 0.01
3	7	0.10	± 0.01
4	7	0.08	± 0.01
5	8	0.10	± 0.01
6	8	0.08	± 0.01
7	7	0.08	± 0.01
8	8	0.09	± 0.01
9	7	0.07	± 0.01
10	8	0.09	± 0.01
all		0.085	

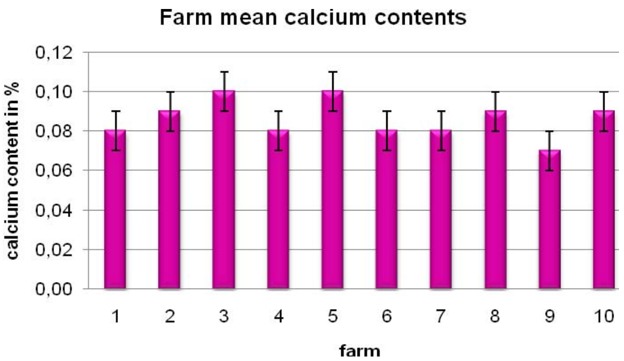

Fig. 91 Farm mean calcium contents in %

Fixed effect breed does not have a significant influence on calcium content (Pr > F = 0.9122) (Table 74, Fig. 92). Mean breed calcium contents is 0.09% for both breeds.

Table 74. Breed mean calcium contents in %

breed	n	Ca% LSMEANS	stderr.
Ankole	37	0.09	± 0.01
cross bred	38	0.09	± 0.01

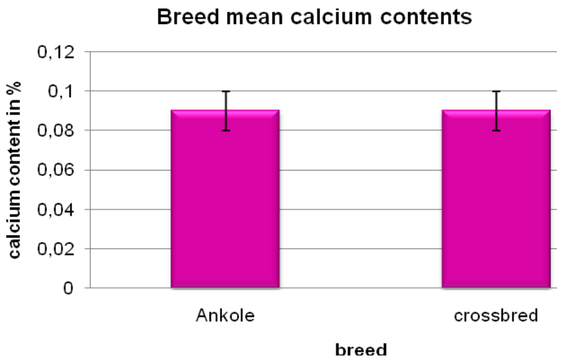

Fig. 92 Breed mean calcium contents in %

Fixed effect season does not have a significant influence on calcium content (Pr > F = 0.4442) (Table 75, Fig. 93). Season mean calcium contents are 0.08% for samples collected during late dry season and 0.09% for samples collected during early wet season.

Table 75. Season mean calcium contents in %

season	n	Ca% LSMEANS	stderr.
late dry	37	0.08	± 0.01
early wet	38	0.09	± 0.01

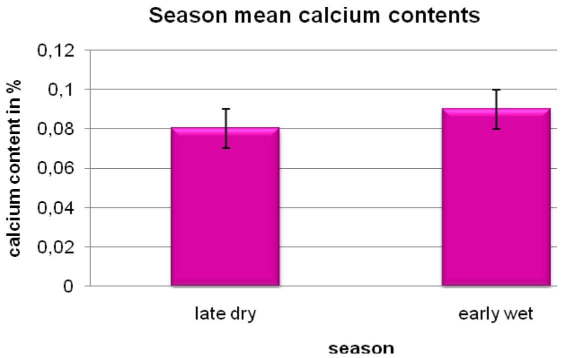

Fig. 93 Season mean calcium contents in %

There is no significant influence of interaction between farm and breed on calcium content (Pr > F = 0.8676) (Table 76, Fig. 94). Pasture mean calcium contents ranges from 0.06% (farm 9, crossbred pasture) to 0.12% (farm 3, Ankole pasture) (mean: 0.09%, median: 0.09%). For samples from Ankole pastures mean calcium contents range from 0.07% (farms 1 and 7) to 0.12% (farm 3) (mean: 0.09%, median: 0.08%). For samples from crossbred pastures mean calcium contents range from 0.06% (farm 9) to 0.10% (farms 2,5 and 8) (mean: 0.09, median: 0.09). Pasture mean calcium contents are very homogenous across all farms.

Table 76. Pasture mean calcium contents in %

		Ankole			crossbred	
farm	**n**	**Ca% LSMEANS**	**stderr.**	**n**	**Ca% LSMEANS**	**stderr.**
1	3	0.07	± 0.02	4	0.09	± 0.02
2	4	0.08	± 0.02	4	0.10	± 0.02
3	3	0.12	± 0.02	4	0.09	± 0.02
4	4	0.09	± 0.02	3	0.08	± 0.02
5	4	0.10	± 0.02	4	0.10	± 0.02
6	4	0.08	± 0.02	4	0.08	± 0.02
7	4	0.07	± 0.02	3	0.09	± 0.02
8	4	0.09	± 0.02	4	0.10	± 0.02
9	3	0.09	± 0.02	4	0.06	± 0.02
10	4	0.08	± 0.02	4	0.09	± 0.02

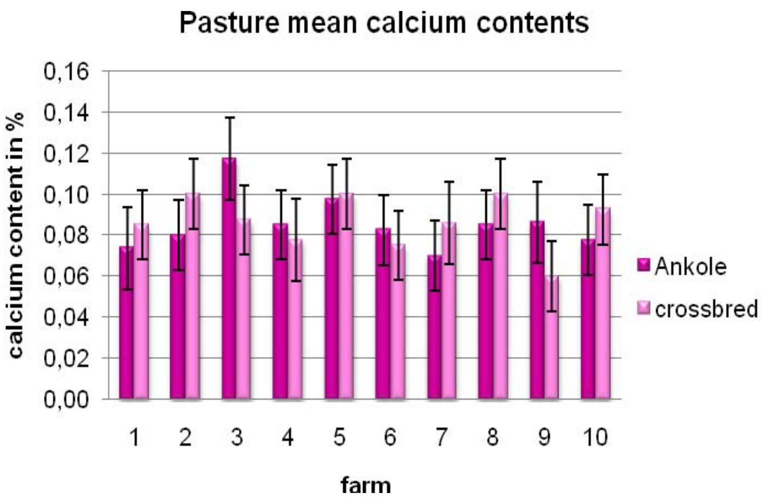

Fig. 94 Pasture mean calcium contents in %

There is no significant influence of interaction between season and breed on calcium content (Pr > F = 0.2876) (Table 77, Fig. 95).

Mean calcium contents for samples collected during late dry season are 0.09% on Ankole and 0.08% on crossbred pastures. Mean calcium contents for samples collected during early wet season are 0.08% for Ankole and 0.09% for crossbred pastures.

Calcium contents during late dry season are higher on Ankole pastures. Calcium contents during early wet season are higher on crossbred pastures.

Table 77. Seasonal breed mean calcium contents in %

breed	season	n	Ca% LSMEANS	stderr.
Ankole	late dry	18	0.09	0.01
Ankole	early wet	19	0.08	0.01
cross bred	late dry	19	0.08	0.01
cross bred	early wet	19	0.09	0.01

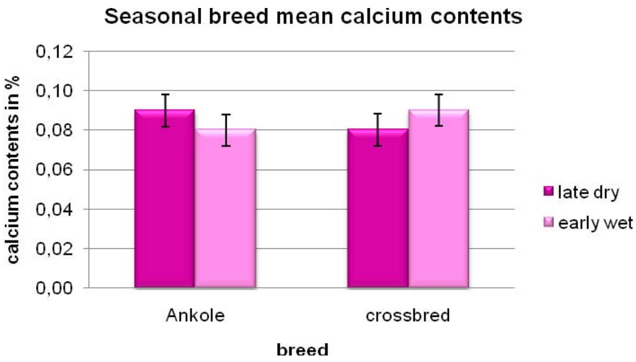

Fig. 95 Seasonal breed mean calcium contents in %

4.6. Summary of results

Following chapter sums up significant results separated according to data pools.

Pasture management

There are differences in pasture management between pastures stocked with different herd types. On most farms (6 out of 9) Ankole pastures are more spacious than crossbred pastures. Mean and median sizes of Ankole pastures are a lot larger than crossbred pastures. Mean/median sizes of Ankole pastures are also larger than overall mean/median pasture size.

Pasture yield was estimated to be medium or high for crossbred pastures but rather low or medium for Ankole pastures. The same is the case for pasture quality. Crossbred pastures were estimated to be of rather medium or high quality. Ankole pastures were estimated to be of rather low or medium quality. Ankole cattle was more likely than crossbred cattle to be kept permanently on the same pasture. No crossbred, but 4 Ankole pastures were described to be subjected to erosion.

Farmers keep crossbred cattle on pastures where water is readily available, which have undergone pasture improvement and which supply high quality feed to cattle. Other requirements for crossbred cattle are, that the area had been cleared in advance, that pastures were close to the homestead and that there were no weeds present. Reasons for suitability of a pasture for Ankole were almost exactly opposite.

Pasture vegetation

According to farmers there has been a change in pasture composition. Plants have disappeared and new plants have appeared during the past decade. Most farmers noted a disappearance of certain plants during the past decade. Plants that have disappeared were 3 plants classified as “good” by most farmers (*Hyparrhenia rufa, Chloris gayana and Brachiaria sp.*). Plants that have been noticed to appear on pastures during the past decade were all classified as “bad” plants by farmers (*Cymbopogon afronardus, Sporobolus pyramidalis, Lantana camara* and “Marende”).

Plant species causing problems are independent from herd type a pasture is stocked with. More species have been named to cause problems on crossbred than Ankole pastures. More different problems have been named to be caused by plants on crossbred than Ankole pastures.

An increase of bushes and shrubs was reported for most pastures assessed (60% of crossbred and Ankole pastures). The extent to which pastures stocked with different breeds are affected by a growing abundance of bushes and shrubs varies. More crossbred pastures than Ankole pastures are highly effected by an increase of bushes and shrubs. Ankole pastures are most likely to be affected by increase of bushes and shrubs to a moderate degree.

An increase of trees has been noticed by farmers on a higher percentage of Ankole than crossbred pastures. Extent of increase was rather moderate or high for Ankole pastures and rather small or moderate for crossbred pastures. Decrease of trees was blamed on bush clearing activities and unreliable rains. Reasons were the same, independent from herd type.

Plant traits

Overall mean plant height is 21.70cm. There were significant differences between samples collected from different farms. There was a highly significant difference in plant heights between pastures stocked with different breeds (Ankole: 18.97cm, crossbred: 25.04cm). Significant differences in plant height between pastures stocked with different breeds were recorded for several farms (Table 78):

Table 78. Significant difference in plant height within farms

farm	pasture with larger plants stocked with:
1	crossbred herd
2	Ankole herd
3	crossbred herd
5	crossbred herd
7	crossbred herd

Where significant differences between pastures on one farm occurred, plants were found to be mostly larger on crossbred pastures.

Overall mean reproductive height is 35.42cm. There were significant differences in reproductive heights between different farms. There was a significant difference in reproductive height between pastures stocked with different breeds (Ankole: 30.5cm, crossbred: 41.52cm).

Overall mean leaf width is 6.79mm. There were highly significant differences in leaf width between plants collected on different farms. Highly significant differences in leaf width between pastures stocked with different breeds were recorded for several farms (Table 79):

Table 79. Significant difference in leaf width within farms

farm	pasture with wider leaves stocked with:
2	crossbred herd
4	crossbred herd
5	Ankole herd
6	crossbred herd
8	Ankole herd

On 3 farms with significant differences in leaf width between pastures leaves were wider on crossbred pastures. On 2 farms with significant differences leaves were wider on Ankole pastures.

Overall mean leaf length is 102.74mm. There were highly significant differences of leaf length between plants collected on different farms. There was a highly significant difference in leaf length between pastures stocked with different breeds (Ankole: 89.12mm, crossbred: 121.65mm). Leaves were shorter than overall mean on Ankole pastures. Leaves were longer than overall mean on crossbred pastures. Highly significant differences in leaf length between pastures stocked with different breeds were recorded for several farms (Table 80).

Table 80. Significant difference in leaf length within farms

farm	pasture with longer leaves stocked with:
1	crossbred herd
3	crossbred herd
5	crossbred herd
7	crossbred herd

On all farms with significantly different leaf length between pastures, leaves on crossbred pastured were longer.

Category life form did not show noteworthy differences between pastures stocked with different breeds. Major difference was, that leguminous plants were only recorded on crossbred pastures. But with 0.2% of plants on crossbred pastures being leguminous, they do not represent an important group.

No major difference between pastures stocked with different herd types was recorded for growth form. Most plants on both pasture types were classified into 3 major groups. More growth form categories were recorded for crossbred pastures (7 compared to 5 for Ankole pastures), but additionally to 3 major groups identical for both pasture types, only small numbers of individuals were classified into these extra categories.

Clonality did not show a major difference between pasture types. Almost all plants found were recorded as not clonal.

Spinescence did not show a major difference between pasture types. Almost no plants had spines. All 10 plants recorded to have spines were found on Ankole pastures.

Pasture productivity

Results for fresh matter yield, dry matter yield and dry matter content vary in significance between pastures stocked with different breeds and samples collected during different seasons (Table 81).

Table 81. Pasture yields seperated by breed and seson

	fresh matter, t/ha LSMEANS	**stderr.**	**dry matter, t/ha LSMEANS**	**stderr.**	**dry matter, % LSMEANS**	**stderr.**
breed						
Ankole	5.33^{a}	± 0.03	1.96^{a}	± 0.05	36.84	± 0.86
crossbred	5.44^{b}	± 0.03	2.13^{b}	± 0.10	39.13	± 1.04
season						
late dry	5.33^{a}	± 0.03	1.97	± 0.05	36.96	± 0.86
early wet	5.44^{b}	± 0.03	2.12	± 0.10	39.01	± 1.04
overall	5.39		2.04		37.79	

Overall mean fresh matter is 5.39t/ha. There is a significant difference in fresh matter yield between pastures stocked with different breeds (Ankole: 5.33t/ha, crossbred 5.44t/ha). Mean fresh matter yield on Ankole pastures is lower than overall mean. Mean fresh matter yield on crossbred pastures is higher than overall mean. There is a significant difference between fresh matter yield during different seasons (late dry season: 5.33, early wet season: 5.44). Fresh matter yield during late dry season is lower than overall mean. Fresh matter yield during early wet season is higher than overall mean.

Overall dry matter yield is 2.04t/ha. There are highly significant differences between mean dry matter yields of different farms. There is a significant difference between dry matter yield of pastures stocked with different breeds (Ankole: 1.96t/ha, crossbred: 2.13t/ha). Dry matter yield on Ankole pastures is lower than overall mean. Dry matter yield on crossbred pastures is higher than overall mean. Highly significant differences of dry matter yield between pastures within farms were calculated for 2 farms: On farm 3 and farm 5 dry matter yield was significantly higher on crossbred pastures.

Annual dry matter yield can not be estimated in this study due to temporal restrictions of trial design.

Overall mean dry matter content is 37.79%. There are highly significant differences between dry matter content of pasture samples collected on different farms. A highly significant difference of dry matter content between pastures within a farm was calculated for farm 5 (Ankole pasture: 25.96%, crossbred pasture 47.84%). Interaction of farm and season has a significant impact on dry matter percent. There was no significant difference in dry matter content between samples from different seasons collected on a single farm. Significant differences must therefore occur between samples collected during different seasons on different farms.

Nutrient analyses

Results are summarised for factors breed and season (Table 82). Only crude protein content in percent showed a significant difference between farms and pastures stocked with different breeds.

Table 82. All results for nutrient analysis separated by breed and season

	CP % LSMEANS (n=76)	stderr.	NDF % LSMEANS (n=76)	stderr.	P % LSMEANS (n=76)	stderr.	Ca % LSMEANS (n=75)	stderr.
breed								
Ankole	7.25[a]	± 0.28	69.77	± 1.79	0.20	± 0.02	0.09	± 0.07
crossbred	6.30[b]	± 0.28	72.82	± 1.78	0.16	± 0.019	0.09	± 0.07
season								
late dry	6.96	± 0.29	73.4	± 1.81	0.19	± 0.02	0.08	± 0.01
early wet	6.59	± 0.28	69.19	± 1.75	0.17	± 0.02	0.09	± 0.01
overall mean	6.71		71.36		0.18		0.085	

Gross energy content does not change significantly between pastures stocked with different breeds or samples collected during different seasons (Table 83).

Table 83. Gross energy contents in different units across breeds and seasons

	GE kcal/g LSMEAN (n=8)	stderr.	GE in Mcal/kg	GE in MJ/kg
breed				
Ankole	4.00	0.10	4.00	16.74
crossbred	3.94	0.10	3.94	16.49
season				
late dry	3.98	0.10	3.98	16.66
early wet	3.98	0.10	3.98	16.66

Gross energy contents have been analysed for 8 samples collected during both data collection periods on 1 farm only (farm 1). To be able to make some predictions for stocking rates, mean gross energy contents per breed and season have been multiplied with mean dry matter contents per breed and season determined during this study. This serves to roughly estimate how much mean gross energy 1ha of Ankole and crossbred pasture could theoretically yield. Estimates are also made for 1ha of pasture during late dry and early wet season (Table 84).

Table 84. Estimated gross energy yields per ha separated by breed and season

	dry matter, t/ha LSMEANS	stderr.	GE in MJ/t	GE in MJ/ha
breed				
Ankole	1.96	± 0.05	16740.00	32810.4
crossbred	2.13	± 0.10	16488.90	35121.4
season				
late dry	1.97	± 0.05	16656.30	32812.9
early wet	2.12	± 0.10	16656.30	35311.4

Referring to nutrient and energy values recommended in literature the capacity of pastures analysed in course of this study could now be estimated (Table 85). Estimated mean gross energy yield for crossbred pastures is higher than for Ankole pastures. The difference comprises approximately 2300MJ/ha. The same difference has been calculated for estimated mean gross energy yield per ha between late dry and early wet season.

5. Discussion and conclusion

Pasture management

The first hypothesis of this study was, that there is no difference in pasture management between breeds. According to results this has to be rejected as there are differences in pasture management between pastures, stocked with different breeds.

Intensity of pasture management varies between farms and breeds. Most farmers hardly separate different grazing areas by fences. Animals are herded which might be a reason why division of grazing land by fences is not pronounced on most farms. 3 farms have a higher number of fenced off paddocks than most farms (6, 9 and 10 single paddocks respectively). This indicates that these farms put a greater emphasis on grazing control by fencing off grazing areas.

Paddock sizes varied greatly between farms and pastures stocked with different breeds. Mean size of Ankole pastures was larger. Size differences between pastures stocked with different breeds were bigger on those farms, where Ankole pastures were larger than crossbred pastures. Reasons for this can only be guessed. It may depend on total farm and/or herd size. But the pronounced differences in pasture size, on farms where crossbred pastures are larger, is interesting. A few more details on the 3 farms with larger crossbred than Ankole pasture may allow some kind of interpretation.

Farm 1 kept their Ankole cattle on a pasture of a different property far away from the homestead. The crossbred pasture was enclosing the homestead. Apart from better quality of the crossbred pasture, the higher maintenance herd (crossbred herd) was also closer to homestead and cattle handling facilities. In having shifted the Ankole herd to a different area might lie the explanation of the larger amount of land dedicated to the crossbred herd on this farm.

Farm 2 puts a lot of work into pasture management. With 10 paddocks in total, rotational grazing for the crossbred herd (which alone occupies 9 paddocks) and pasture conservation by making hay this farm stands out among the rest of study farms. The crossbred pasture chosen for analysis was situated on flat area at the valley floor. It was lightly covered by trees and herbaceous vegetation was dense. Situation of the Ankole pasture was quite different. There were a lot of bushes, trees and shrubs growing in the lower part of the pasture. The ground was very wet, almost swampy. Lemongrass was present in high abundance. The upper part of the Ankole pasture was situated on a steep hillside which was also quite overgrown with bushes, shrubs and trees and apparently quite dry. Herbaceous vegetation was not very dense in the upper pasture area. So assumed better quality of the crossbred pasture was particularly obvious on this farm. Taking high management inputs into account this farm seems to be gaining a lot from their way of keeping it´s crossbred herd. This might explain the dedication of a larger area to crossbred cattle than to Ankole cattle. Farm 1 and farm 2 were also study farms with largest combined pasture sizes (161ha and 185ha respectively).

Combined size of Ankole and crossbred pasture on farm 8 was about average (115ha). This farm is practising a separation of crossbred and Ankole herd for the longest time of all study farms. Since 22 years herds are kept separately. Maybe greater experience with crossbred cattle on this farm is an explanation why they graze on larger pasture than the Ankole herd. The long time period may have provided the farm with enough experience and knowledge about how to manage their pastures to meet crossbred herds need. They may have had good quality pasture from the start or improved their pasture condition enough to sufficiently supply their crossbred herd. And as they dedicated a larger part of their land to crossbred cattle, their economic return must justify their management decisions.But these explanations for larger size of crossbred pastures on farms concerned are assumptions only as reasons were not inquired from farmers. Still it shows how farms differ from each other in regard to their pasture management.

Higher likeliness of Ankole herds to be kept permanently on a paddock indicates a slight distinction between pastures stocked with different breeds. Even by such relatively simple measures as dividing grazing areas and transferring cattle between thus created paddocks, pastures stocked with crossbred cattle are treated differently from pastures stocked with Ankole cattle. The special case of 1 farm with 9 separated paddocks for crossbred cattle opposing 1 paddock for Ankole cattle shows how differently farmers might manage different breeds´ grazing schedule.

Reasons farmers gave for suitability of a plot imply, that from their experience, crossbred cattle place greater demands on pasture management than Ankole cattle. Reasons given express a higher need of pasture management/improvement for crossbred pastures. All reasons imply that farmers choose what they consider their “better” pastures for crossbred cattle and enhance pasture quantity and quality by concentrating management efforts on these plots. As breeds such as Holstein Friesian [and consequential crossbred Ankole x Holstein Friesian cattle as well] have higher maintenance requirements than most tropical indigenous breeds (Chamberlain, 1989) choice of higher quality pastures for crossbred cattle is only logical.

Reasons for suitability lead to the assumption that pastures not fit for crossbred cattle are still considered fit for Ankole cattle. According to farmers Ankole can bear pastures of poorer quality. This may also explain that larger size of most Ankole pastures is expected to balance minor pasture quality in sustaining Ankole herds. This predetermined discrimination between herd types may be the main reason, why certain parameters analysed show differences between samples collected from pastures stocked with different breeds.

Pasture improvement was done on almost all pastures. The only pasture, where no improvement methods were applied, was an Ankole pasture. Methods applied by farmers are mentioned in literature to be useful for pasture improvement (Jameson, 1970 and Sabiiti, 2001). Control of weeds, poisonous plants and bush regrowth are important practices which can greatly enhance pasture productivity (Mugerwa, 2001). Recommendation in literature for further improvement includes changing herd structure (with concentration on stocking rates), genetic improvement, health management and animal husbandry (Mugerwa, 2001).

Overgrazing has led to degradation of rangelands through vegetation change and soil erosion (Twinamasiko, 2001). Erosion has been found to effect only Ankole pastures of pastures selected for this study. The hypothesis that there is no difference in the impact of erosion on pastures stocked with different breeds therefore has to be rejected. Higher likeliness of Ankole pastures to be stocked permanently and shorter intervalls between disturbances, as indicated by lower mean plant height on Ankole pastures in this study, may support the interpretation, that Ankole pastures may be subjected to overgrazing. The greater increase of bushes, shrubs and trees could also be a sign for degradation of pasture.

Pasture vegetation

Recognition of pastoralists´ indigenous ecological knowledge is fundamental for the success of range management programs in East Africa (Mapinduzi et al., 2003). Collection of indigenous knowledge in this study was not a central objective. Still it provides valuable, additional information.

Grazing has potential to produce major shifts in species composition (Diaz et al., 1994 in Diaz et al., 1999). Although literature reports, that floras show little response to disturbances that have been there for a long time (Lavorel et al, 1999) most farmers reported an appearance of new plants and disappearance of known plants during the past decade. Interestingly all plants reported to have disappeared were classified as “good” plants by farmers. On the other hand all plants that have newly appeared have been classified as “bad” plants. One could interpret this result as a proof of ongoing decline of pasture quality. But it may just show that farmer perception on compositional changes concentrates on plants with special importance to farmers, whether positive or negative. The extend of composition change has not been assessed and it is hard to decide, whether introduction of crossbred cattle has influenced pasture composition on sample pastures. Separation of crossbred cattle from Ankole has been happening over the last 8 to 22 years. Duration varied greatly between farms. It has not been ascertained if different breeds have always been kept on the same pastures. Therefore it cannot be deduced from answers given by farmers, that introduction of crossbred cattle has been a reason for occurring changes in pasture composition.

It was hypothesized, that there is no difference in bush, shrub and tree abundance between pastures stocked with different breeds. Results from questionnaires show, that farmers estimated an increase of bushes and shrubs on the same percentage of Ankole and crossbred pastures. Varying between pastures stocked with different breeds is only the extent to which pastures are affected by increase of bushes and shrubs. Crossbred pastures were estimated to be affected to a higher extent than Ankole pastures by an increase of bushes and shrubs. Shrubs may affect grassland plants negatively by competition, positively by serving as grazing refuge, or neutrally (Pihlgren & Lennartsson, 2008). The extent to which pastures are affected is important, but also whether the impact of an increase of bushes and shrubs is positive or negative for pasture development. It has not been assessed in this study whether the impact of increase of bushes and shrubs is positive or negative. It would be a good idea to enter further into this matter in future studies in the area concerned. But farmers apply bush clearing to almost all pastures analysed. It can therefore be assumed, that negative effects of an increase of bushes and shrubs outweigh positive effects, otherwise farmers would not see the need of bush clearing.

More Ankole than crossbred pastures were affected by an increase of trees. There was a difference between pastures stocked with different breeds in the extent, to which pastures were affected by an increase of trees (Ankole pastures more affected than crossbred pastures). Trees may affect the productivity of grazing systems by altering pasture productivity, quality, or species composition (Jackson & Ash, 2001). Trees affect growth of pasture plants around them by altering availability of resources (Scholes & Walker, 1993 in Jackson & Ash, 2001). But trees may also have a beneficial effect on pasture quality (Sabiiti, 2001 in Mukiibi, 2001b) and animal welfare by providing shade (Valtorta et al., 1997). Whether positive or negative effects of an increase of trees are of greater consequence was not asked during the survey. But as trees, apart from leguminous trees appreciated for their nitrogen fixing capacity, are also cleared from pastures, it can be assumed, that negative effects are of greater consequence.

There are several conflicting views as to what increases the number of trees, shrubs and thickets. Following reasons are suggested: low soil fertility, termitaria, reduction of cattle and human population, grazing/browsing pressure, changes in fire regime insufficient availiability of water and livestock diseases (Sabiiti, 2001). Low soil fertility could be one of the reasons why Ankole pastures are affected to a greater extent by growing tree, bush and shrub abundance as farmers choose lower quality pastures for Ankole cattle. Lower soil fertility would affect pasture yield and quality and result in lower yield and quality of pastures. Farmers have mentioned, that water availability does not have priority for the dedication of a pasture to Ankole cattle. The assumed responsibility of insufficient availiability of water for an increase of trees, bushes and shrubs could also explain the higher extent to which this is taking place on Ankole pastures. If increasing grazing pressure is responsible for the increase of trees, shrubs and thickets this may be a sign for overgrazing of Ankole pastures.

If personal expression gathered during field work is taken into account, appearances of pastures lead to conjecture, that pastures stocked with different herd types are managed differently. Assumptions of this sort are based on visual differences of both herbaceous flora and also non herbaceous flora (shrubs and trees). These observations were just recorded but not analysed by any scientific means and aim at providing an insight into the situation of pastures found at the time of data collection.

Crossbred pastures were usually well maintained. Non herbaceous flora was not very dense, in most cases, compared to most Ankole pastures (Fig. 96, Fig. 97). Although shrubs and trees are essential parts of crossbred pastures as well their abundance was usually smaller on crossbred than on Ankole pastures. Leguminous trees are kept for their nitrogen fixation capacity (Fig. 99). Judged from personal impression *Cymbopogon afronardus* was less abundant on crossbred pastures. On some crossbred pastures, sward height was much larger than on Ankole pasture assessed (Fig. 98).

Fig. 96 Open area on crossbred pasture (farm 4)

Fig. 97 No major tree growth on crossbred pasture (farm 7)

Fig. 98 Sward height on crossbred pasture (farm 5)

Fig. 99 Leguminous tree on crossbred pasture (farm 8)

In some Ankole pastures sheer abundance of weeds like *Cymbopogon afronardus*, shrubs and trees made a lot of pasture badly accessable (Fig. 100, Fig. 101). Sample collection was sometimes difficult on Ankole pastures due to high abundance of bushes, shrubs and trees and also lemongrass tussocks which reached huge dimensions in some cases. *C. afronardus* was observed in a lot of Ankole pastures. In cases where a lot of *C. afronardus* grew and ground in between tussocks was covered with plants more palatable to cattle, sward in between tussocks is relatively low. Palatable plants growing in between *C. afronardus* are well eaten which leads to a lawn like appearance of these sections (Fig. 102, Fig. 103).

According to personal impression gathered during sample collection, there are differences between pastures stocked with Ankole and pastures stocked with crossbred cattle.

Fig. 100 *Cympobogon afronardus* in abundance on Ankole pasture (farm 8)

Fig. 101 High shrub and tree abundance on Ankole pasture (farm 2)

Fig. 102 Lawn like appearance between *Cymbopogon afronardus* on Ankole pasture (farm 3)

Fig. 103 Comparatively low sward height on Ankole pasture (farm 3)

Main plant species causing problems on pastures were the same independent from herd type. More plant species were named to cause problems on crossbred pastures. More problems caused by plants were mentioned for crossbred pastures. There are several possible explanations:

1) There could be more problem causing plants on crossbred pastures. But it seems highly unlikely, than pasture composition varies to such a great deal within farms.

The fact that most prominent plants mentioned by farmers are very similar between pastures stocked with different herds opposes this interpretation. Additionally farmers have been asked whether there are plants that grow on one pasture type only. Only 1 farmer mentioned 1 species that occurred on his crossbred pastures, but not on his Ankole pastures.

2) Ankole cattle may be able to tolerate problem causing plants better than crossbred cattle. So there are less problems caused by plants on Ankole pastures. This would explain the fewer number of plant caused problems mentioned. 4 species have been named to cause problems on crossbred pasture, that were not mentioned to cause problems on Ankole pastures. It could well be, that these species do not affect Ankole cattle. Several farmers mentioned during interviews, that certain plants are not eaten by pure Ankole cattle that would be eaten by crossbred cattle. Animals may ingest poisonous plants resulting in direct economic loss when animals die. Consumption of certain plants may lead to a deterioration of quality of livestock products caused by off-flavours. (Oryokot, 2001). This means it would be interesting, even from an economic viewpoint, to investigate further if Ankole cattle shun certain plants.

3) Farmer are more observant of crossbred herds than Ankole herds as they estimate crossbred herds to be more susceptible to problems. Therefore they also watch crossbred pastures more carefully and notice more problem causing plants and problems than on Ankole pastures.

Plant traits

It was hypothesized, that there are no differences in selected plant functional traits between individual farms and pastures stocked with different breeds. Whether this hypothesis is accepted or rejected has to be adjusted to type of plant trait.

Results of this study show, significant differences in plant height between pastures on different farms and pastures stocked with different breeds. Plant height is associated with competitive vigour, whole plant fecundity and with time intervals plant species are given to grow between disturbances [like grazing] (Weiher et al., 1999, Cornelissen et al., 2003b). Plants display increasing vertical biomass density and height with decreasing disturbance intensity and/or increasing resource supply. An increase in vertical biomass displays either decreasing disturbance or increasing resource supply (Kleyer, 1999). Both could be the case on pastures stocked with crossbred cattle. Plants are generally larger on these pastures.

The preselection to stock pastures of higher quality with crossbred cattle may be the most important factor, why plants were larger on crossbred pastures. Crossbred pastures tend to be estimated to yield better quality than Ankole pastures. Fresh and dry matter yield are significantly higher on crossbred pastures. Higher yields and estimated better quality pasture, hence better availabilty of resources. If increased resource supply leads to higher plants on crossbred pastures decisions made by farmers, which herd is put onto which pasture, may play the most impoftant role.

Larger plant height may be taken as an indicator of longer intervals between grazing. Mean pasture size is much larger for Ankole than for crossbred pastures. This fact could lead to the asumption, that time intervalls between reoccuring disturbance of the same spot would be longer on Ankole than on crossbred pastures. Judging according to smaller plant height on Ankole pastures, the opposite seems to be the case. Due to estimated higher density of bushes and shrubs on Ankole pastures larger pasture size may not be as important as relative proportion of accessible pasture.

Reproductive height was significantly higher on pastures stocked with crossbred cattle. Therefore inflorescences, by being further away from the ground, might be more exposed to damage. Reproductive height may not be a significant trait in this study, as only 8.96% of all plants had inflorescences, which could be measured.

Both leaf traits measured (leaf width and leaf length) were found to be higher on crossbred pastures. Although only leaf width showed a significant difference between pastures stocked with different breeds mean leaf length was also longer on crossbred pastures. These two measurements serve as an alternative for measuring leaf size. It can be assumed that mean leaf size on crossbred pastures is larger than on Ankole pastures. Intense cattle grazing has been proven to lead to an increase of species with small tender leaves (Diaz et al., 2001). Small leaves are a typical mechanism of grazing resistance by grazing avoidance (Briske, 1996). If plants on Ankole pastures have smaller leaves to achieve a greater tolerance to grazing, higher grazing pressure on Ankole pastures could be an interpretation for this result. Plants adapt by reducing leave size. But it might be more reasonable to hold estimated better pasture quality of crossbred pastures accountable for larger size of leaves on crossbred pasture. As plants on crossbred pastures are subjected to grazing likewise and it is questionable if Ankole pastures are grazed to such a greater extent than crossbred pastures.

Life form grass dominates. *Themeda triandra* and *Cymbopogon afronadus*. communities are most common in the study area (Aluma, 2001). They tend to be dominated by grass species so results from this study are in line with literature. Also the extremely low legume content, typical for pastures in Uganda (Mwebaze, 2008), can be confirmed with this study as only 0.10% of all plants measured were legumes. The only noticable difference for trait life form is the sole occurence of legumes in crossbred pastures.

There are no major differences in growth form for plants from pastures stocked with different breeds. Erect plants tend to respond negatively to grazing, prostrate plants tend to respond positively (Diaz, et al., 2007). Most frequent growth from category “short basal” complies with this finding by being a prostrate growth from. For tussocks, second most frequent growth form, in this study, a negative response to grazing has been reported (Diaz et al., 2007). Maybe plants categorised as tussocks in this study do not follow the general trend in responsing negatively to grazing. Another explanation for the high percentage of tussock plants may be that final selection of plants reflects preference of individuals [herbivores] modified by available opportunities (Hodgson, 1979 in McIntyre et al., 1999). Plants which have been categorized as tussocks might not be amidst preferred forage plants for cattle grazing selected pastures. *Cymbopogon afronardus* for example, not eaten by cattle, falls into the tussock category. Especially on Ankole pastures it has been found quite often. “Erect leafy” plants are the third most frequent growth form. This answers to expectations, that erect plants tend to respond negatively to grazing (Diaz, et al., 2007) as the least number of plants found in a major category was categorized as “erect leafy”.

Almost all plants found were categorized as not clonal. Clonality may promote persistance after environmental disturbaces [like grazing] (Cornelissen, et al., 2003b). A global study has shown, that grazing increases abundance of stoloniferous [and therefore clonal] and rosette plants (Diaz et al., 2007). This was not the case in this study and is a surprising result. An explanation might be, that flora in the study area has been subjected to grazing for a very long time and plants may have chosen other ways of adaptation. Another explanation might be that only above ground clonality was classified. So plants may still propagate by below ground clonality, which has not been assessed.

Hardly any plants have been categorised to have spines (only 10 out of 3750 plants). Spinescence plays an obvious role in anti-herbivore defence. Additionally it may play additional roles in reducing heat or drought stress and spiny plants may provide other plant species with refuge from herbivores (McIntyre et al., 1999, Cornelissen et al., 2003b). Reasons for this can only be guessed. Adaptation to grazing might have been following a different path. Spiny plants might also have been considered as weeds and therefore been removed in the past which led to a man-made selection against spiny plants. Additionally measurements were only done on herbaceous understory plants. During data collection bushes, shrubs and trees with some or other form of spines was frequently encountered (sometimes even by physical contact).

So the hypothesis is partly accepted and partly rejected. There were significant differences in continuous traits between farms and pastures stocked with different breeds. There were almost no differences in discontinuous traits between pastures stocked with different breeds. Discontinuous traits have not been analysed on level of individual farms.

Productivity

It was hypothesized, that there is no difference in pasture productivity between individual farms, breeds and seasons. Whether these hypotheses are accepted or rejected depends on the parameter analysed. There are three sources of results relating to productivity: farmers´ estimations of pasture yield and pasture quality, fresh and dry matter yield measured on sample pastures and dry matter content in percent also measured on sample pastures.

Farmers´ estimations for pasture yield naturally varied to a great extent between farms. Farmers estimated a difference in pasture yield between sample pastures stocked with different breeds. Although assessment of pasture productivity on two pastures per farm does not satisfactorily depict pasture yield for a whole farm, a curious fact should be mentioned. Farm 1 estimated the highest percentage of low yielding pasture (66%). Yet dry matter yield result for farm 1 were the highest of all samples collected. The opposite is the case for farm 3. Estimated pasture yield was the highest percentage of high yielding pasture of all farms (95%). Yet result for dry matter yield were the lowest of all farms.

This poses the question of how reliable farmers´ estimations of pasture yields are. 8 out of 10 farmers estimated at least one third of their pastures to be high yielding (5 above 80%). Yet when asked about sampling pastures most were estimated as medium yielding. Another example is that of all pastures assessed only 1 Ankole pasture was reported to be low yielding. Yet 7 out of 10 farmers estimated between 5% and 66% of their pastures to be low yielding. Farmers might bias estimations of pasture yield in favour of their own pastures. It could also be the understandable notion to answer questions of this sort in such a way, that answers might let one´s own situation appear to its best. My interpretation may be wrong. Firstly, it is only based on personal impressions. Secondly in having seen only parts of pastures on all farms, my picture of the situation is fragmentary. As pasture yield and pasture quality are essential for fixing stocking rates further inquest is advisable for future studies.

Estimated pasture quality achieved the same estimates as pasture yield. Estimated percentage of high quality pasture seems quite high (mean of all farms: 57.5%). This suggests that most farmers are content with quality of their pastures. It may also be possible that the discrimination of yield and quality might not have been properly illustrated during interviews which puts the questionnaire on pasture management under criticism. In retrospective the demand of answering questions for pasture yield and quality in percentages of total pasture area might have been suboptimal. It needed a lot of explanatory effort of interviewers to explain the meaning of these questions.

Summing up farmers estimations, pasture yield and quality differ between farms and pastures stocked with different breeds.

There is a significant difference in dry matter yield between different farms and pastures stocked with different breeds. There is no significant difference between dry matter yields of different seasons. Mean dry matter yields measured during this study lie within range of dry matter yields measured in a previous studie of the area (Mugerwa, 2001). The significantly higher mean dry matter yield calculated for crossbred pastures may be explained, as already mentioned, by preselection of higher yielding and higher quality pastures for crossbred cattle. According to a local study season has a significant effect on pasture dry matter yield (Kagoda, 2001). Significant influence of season could not be attested during this study. Four weeks between data collection rounds could be to short a time period to measure an expected pronounced differences between mean dry matter yield of different seasons

There are significant differences between dry matter content of different farms. There are no significant differences between dry matter contents of pastures stocked with different breeds and seasons. Dry matter content in percent measured was above ranges of dry matter percent for 15 species of tropical grasses analysed by Juarez Lagunes et al. (1999) and 7 species of tropical grasses analysed by Mihreteab (2000). It has to be mentioned, that not only grass but also legumes and herbs, although in minute proportions, were parts of pasture samples used for dry matter content which might explain the difference.

In regard of farmers estimations there is a difference in pasture productivity between pastures stocked with different breeds and between farms. The hypotheses have to be rejected as far as estimations go. Regarding dry matter yield, the hypotheses have to be rejected for farms and breeds but accepted for different seasons. Regarding dry matter content in percent, the hypotheses has to be accepted for farms, but rejected for breeds and seasons. So results from this study, regarding pasture productivity, are inconclusive.

Nutrients

The last hypothesis for this thesis was, that there is no differences in selected nutrients of pasture samples from different farms, breeds and seasons. This hypothesis has to be accepted for all nutrient results, except for crude protein content.

Nutrients required for milk production depend on milk yield and composition. As milk production increases, higher quality diet is needed (Chamberlain, 1989).

Table 85. Recommended nutrient content of rations for lactating cows (Chamberlain, 1989)

lactating cow rations		
weight	≤ 400/500	≤ 400/500
daily milk yields (kg)	< 8/11	8-13/11-17
nutrient concentration		
ME, Mcal/kg	2.36	2.53
crude protein %	13.00	14.00
crude fibre %	17.00	17.00
calcium, %	0.43	0.48
phosphorus, %	0.31	0.34

Gross energy analysis showed that there is no difference in values measured for samples collected from pastures stocked with different breeds or during different seasons. Metabolizable energy of tropical grasses from the study area reached between 9.12 MJ/kg dm and 10.97 MJ/kg dry matter (Mihreteab, 2000). Gross energy contents cannot be compared to metabolizable energy contents. To calculate metabolizable energy, faecel energy and urinary energy + CH_4 would have to be subtracted from gross energy content (Fuller, 2004). So results from this study can only show, that there are no differences in gross energy between samples collected from pastures stocked with different breeds or between samples collected during different seasons. The information gained can be useful as comparative values for further studies on pasture quality.

Overall mean crude protein content lies within range measured by other studies in the same area (Long et al., 1969, Mihreteab, 2000). Compared to temperate zone pastures, with crude protein contents around 20% (Wienmann, 1955), average crude protein contents measured were rather low. Measured contents fall short of recommended daily crude protein intake for lactating cows (Table 85). Crude protein content was the only chemical parameter assessed, that showed a significant difference on pastures stocked with different breeds. It was higher in samples taken from Ankole than crossbred pastures. Reasons can only be assumed. Crossbred cows with higher nutrient requirements due to their higher production capability (Chamberlain, 1989) may select their forage very carefully and therefore strongly select for protein rich plants. Tree foliage is increasingly recognized as a potentially high quality feed resource for ruminants, particularly to supply crude protein (Leng, 1997). So both herd types might satisfy parts of their protein requirements by consuming leaves off bushes, shrubs and trees.

Neutral detergent fibre content lie within the range of previous studies in the same area (Mihreteab, 2000, Kagoda, 2001). A significant seasonal difference of ndf contents has been reported. Maximum ndf content occured during long dry season, minium during long wet season (Kagoda, 2001). Results from this study show no significant difference in ndf content between samples collected during different seasons. As only four weeks lie between data collection rounds, shortness of time interval could be the reason why there was no pronounced difference between ndf contents of samples collected during different seasons for this study.

Phosphorus content of pasture samples analysed in this study was slightly lower than in previous studies (Mihreteab, 2000) conducted in the same area. It did not reach a recommended level of phosphorus in rations for dairy cows (Table 85).

Calcium values measured in this study were lower than values measured in previous studies in the same area (Mihreteab, 2000). It did not reach a recommended level of phosphorus in rations for dairy cows (Table 85). Calcium contents measured seem to be very low as calcium contents of most tropical grasses range from 0.33% to 0.47% (Minson, 1990 in Rubanza et al., 2005).

Lack of significant differences in nutrient values measured for samples collected in course of this study suggest, that apart from crude protein content, there are no differences in analysed nutrients between farms, pastures stocked with different breeds or seasons.

Finally this study shows, that there are some differences in tested parameters between pastures on different farms. There are some differences in tested parameters between pastures stocked with different breeds. There are also some differences in tested parameters between samples collected during different season. But whether crossbreeding Ankole with Holstein Friesian cattle is accountable for differences cannot be assured. Rather than the introduction of a different breed, accompanying discrimination in herd and pasture management could be the main reasons for differences between pastures on different farms, between pastures stocked with different breeds and between samples collected during different seasons.

The main contribution of this study may be results from surveys of pasture management and pasture vegetation, which have revealed that there are indeed differences in management between farms and pastures stocked with different breeds. These results may serve as enticements for further studies about pastures in the study area to ascertain, if introduction of crossbreeding strategy has an influence on pasture quantity and quality.

6. Summary

This thesis is part of a joint project of ILRI and BOKU called “Evaluation of ecological and economic sustainability of breeding strategies in pastoral systems: The case of Ankole cattle in Uganda”. The practice of pastoralists in south-west Uganda has led to the introduction of crossbreeding Holstein Friesian bulls with indigenous Ankole cattle. Aim of this breeding strategy is to enhance milk yields and therefore productivity of milk cattle enterprises in the area. Pastoralists have therefore split their herds of indigenous Ankole cattle in two leaving one herd purebred and mating the other herd with Holstein Friesian bulls. One of the questions is, if this strategy has a negative influence on pastures.

The aim of this thesis was, to contribute pasture data to the project. The main goal of this work was to identify, if there are differences of pastures stocked with different breeds. Data on pasture management and pasture vegetation was provided by farmers through questionnaire based interviews conducted of ten of the farms participating in the project. On each of these farms, 2 pastures were selected. 1 pasture was stocked with the Ankole, the other pasture stocked with the Ankole x Holstein Friesian herd. Plant traits influenced by grazing were selected and measured by conducting 2 “trait transects” on each of the selected pastures. At transect sites pasture productivity samples were taken during to time intervals separated by approximately 4 weeks. Additionally dominant herbaceous pasture vegetation was sampled and given to farmers for identification. Data on plant qualities was also collected. Pasture samples were taken to Makarere University, Kampala, Uganda and analysed for nutrients of vital importance for milk production.

Analysis of the collected data has lead to following results:

There are differences in pasture management pastures stocked with different breeds. There are also differences in the extent to which bushes, shrubs and trees affect pastures between pastures stocked with different breeds. Pastures grazed by Ankole cattle were more likely to be subjected to erosion. Composition of herbaceous pasture vegetation is changing. Problems caused by weeds are independent from herd type a pasture is stocked with. There are significant differences in some plant traits between pastures stocked with different breeds. Fresh and dry matter yields are significantly different but dry matter content did not show significant differences between pastures stocked with different breeds. Of all nutrients analyzed only crude protein content showed significant differences between pastures stocked with different breeds.

Various reasons for the occurring differences are discussed. But the most important reason may be the preselection of better pastures for crossbred cattle acknowledged by farmers.

7. Zusammenfassung

Die vorliegende Diplomarbeit ist Teil des ILRI-BOKU-Projektes: "Evaluierung ökologischer und ökonomischer Nachhaltigkeit von Zuchtstrategien in Weidehaltungssystemen: der Fall der Ankole Rinder in Uganda". Viehalter im südwestlichen Uganda kreuzen Holstein Friesen Stieren mit autochthonen Ankole Rindern. Das Ziel dieser Zuchtstrategie ist eine Erhöhung des Milchertrages und somit der Produktivität von Milchviehbetrieben in der Gegend. Viehhalter teilten aus diesem Grund ihre ursprüngliche Herde: ein Teil besteht aus reinrassigen Ankole Rindern, der andere Teil besteht aus Kreuzungstiere (Ankole x Holstein Friesen). Eine der Fragen, die sich aus dieser Vorgehensweise heraus stellt ist die, ob sich die Einführung der Kreuzungszucht mit Holstein Friesen negativ auf Weiden auswirkt.

Das Ziel dieser Arbeit ist ein Beitrag von Weidedaten zum Gesamtprojekt. Das Hauptziel liegt darin festzustellen, ob es Unterschiede zwischen Weiden gibt, die mit unterschiedlichen Rassen, oder Herdentypen, bestoßen werden. Daten über Weidemanagement und Weidevegetation wurde mit Hilfe von fragebogengestützten Interviews mit Bauern von 10 Projektbetrieben gesammelt. Auf jedem dieser Betriebe wurden 2 Weiden ausgewählt. 1 Weide beweidet durch Ankole Rinder, die andere Weide beweidet durch Ankole x Holstein Friesen Kreuzungstiere. Pflanzeneigenschaften, die durch Beweidung beeinflusst werden, wurden ausgewählt und mit Hilfe von 2 „trait transects" je Weide gemessen. Weideertragsproben wurden an den Stellen, an denen Transekte durchgeführt wurden, gesammelt. Weideertragsproben wurden in zwei Durchgängen, die durch etwa 4 Wochen voneinander getrennt waren, gesammelt. Zusätzlich zu diesen Daten wurden Exemplare der dominanten, krautigen Spezies gesammelt und den Bauern zur Identifikation vorgelegt. Die Weideproben wurden an der Makarere Universität, Kampala, Uganda zur Bestimmung ihrer Nährstoffzusammensetzung untersucht. Die Analysen konzentrierten sich auf Nährstoffe, die essentiell für die Milchproduktion sind.

Die Auswertung der Daten führte zu folgenden Resultaten:

Es gibt Unterschiede im Weidemanagement und in den Auswirkungen von Büschen, Sträuchern und Bäumen zwischen Weiden, die mit unterschiedlichen Herdentypen bestoßen werden. Ankole Weiden wahren eher von Erosion bedroht. Die Zusammensetzung der krautigen Weidevegetation ändert sich. Unkrautprobleme sind die selben, unabhängig vom Herdentyp. Es gibt signifikante Unterschiede einiger Pflanzeneigenschaften zwischen Weiden, die mit unterschiedlichen Herdentypen bestoßen werden. Frisch- und Trockenmasseertrag, nicht jedoch Trockenmassegehalt, sind signifikant unterschiedlich zwischen Weiden, beweidet durch unterschiedliche Herdentypen. Von allen analysierten Nährstoffen fanden sich nur beim Rohproteingehalt signifikante Unterschiede zwischen den Weiden unterschiedlicher Herdentypen.

Unterschiedliche Gründe für die auftretenden Unterschiede werden diskutiert. Der wahrscheinlichste Grund für die auftretenden Unterschiede ist jedoch eine, von vornherein bestehende, Auswahl besserer Weideflächen für die Beweidung durch Kreuzungstiere.

8. References

Aluma, J. R. (2001). Vegetation. In J. K. Mukiibi, *Agriculture in Uganda - Volume I: General Information* (S. 169-185). Kampala, Uganda: Fountain Publishers Ltd.

Andersson, M. C.-K., Shelton, M., Skerman, P., & Victor, J. (2009). *Grassland species profiles*. Abgerufen am 13. 2 2009 von http://www.fao.org/ag/AGP/AGPC/doc/Gbase/Default.htm

Aniku, J. (2001). Soils classification and pedology. In J. K. Mukiibi, *Agriculture in Uganda - Volume I: General Information* (S. 66-103). Kampala, Uganda: Fountain Publishers Ltd.

Ansquer, P., Cruz, P., Prevot, P., Theau, J. P., Jouany, C., & Duru, M. (2004). Are structural traits relevant indicators of fertility level and cutting frequency in natural grasslands? In A. Lüscher, B. Leangros, W. Kessler, O. Huguenin, M. Lobsiger, N. Millar, et al., *Land use systems in Grassland dominated regions. Proceedings of the 20th General Meeting of the European Grassland Federation* (pp. 760-762). Luzern: Hochschulverlag Ag an der ETH Zürich.

Armstrong, D., & Westoby, M. (1993). Seedlings from large seeds tolerate defoliation better: a test using phylogenetically independant contrasts. *Ecology , 74*, S. 1092-1100.

Boer, M., & Stafford Smith, M. (2003). A plant functional approach to the predoctions of changes in Australian rangeland vegetation under grazing and fire. *Journal of Vegetation Science , 14*, S. 333-344.

Boonman, J. (1993). *East African Grasses and Fodders. Their Ecology and Husbanrdy.* Netherlands: Kluwert Academic Publishers.

Brendon, R., & Wilson, J. (1963). The chemical composition and nutritive value of grasses from semi-arid areas of Karamoja as related to ecology adn types of soil. *East African Agricultural Journal , 29*, S. 134-142.

Briske, D. (1996). Strategies of plant survival in grazed systems: a functional interpretation. In J. Hodgson, & A. Illius, *The ecology and management of grazing systmes* (S. 33-67). oxon: CAB International.

Camerik, A., & Werger, M. (1981). Leaf characteristics of the high platuea of Itaiaia, Brazil. *Biotropica , 13*, S. 39-48.

Chamberlain, A. (1989). *Milk Production in the Tropics.* (W. Payne, Hrsg.) Essex, England: Longman Group UK Limited.

Chenery, E. (1960). *An introduction to the soils of the Uganda Protectorate. Memoirs of the Research Division Series I, number 1. Soils.* Uganda: Department of Agriculture.

Cole, T. C. (2008). *Wörterbuch der Biologie/Dictionary of biology.* Heidelberg: Spektrum Akademischer Verlag.

Cook, B. P.-K. (2005). *Tropical Forages: an interactive selection tool.* Abgerufen am 18. 12 2008 von http://www.tropicalforages.info

Cook, B. P.-K. (2005). *www.tropicalforages.info*. Abgerufen am 13. 1 2009 von http://www.tropicalforages.info/index.htm

Cornelissen, J., Cerabolini, B., Castro-Diez, P., Villar-Salvador, P., Montserrat-Marti, G., Puyravaud, J. P., et al. (2003). Functional traits of woody plants: correspondence of species rankings between field adults and laboratory grown seedlings. (IAVS, Ed.) *Journal of Vegetation Science , 14*, pp. 311-322.

Cornelissen, J., Lavorel, S., Garnier, E., Diaz, S., Buchmann, N., Gurvich, D. E., et al. (2003b). A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. *Australian Journal of Botany , 51*, S. 335-380.

Davies, (2001), S. *n.n.* n.n: n.n.

Diaz, S., Acosta, A., & Cabido, M. (1994). Grazing and the phenology of flowering and fruiting in a montane grassland in Argentia: a niche approach. *Oikos , 70*, S. 287-295.

Diaz, S., Cabido, M., Zak, M., Martinez Carretero, E., & Aranibar, J. (1999). Plant functional traits, ecosystem structure and land use history along a climatic gradient in central-western Argentinia. (IAVS, Hrsg.) *Journal of Vegetation Sciences , 10*, S. 651-660.

Diaz, S., Lavorel, S., McIntyre, S., Falczuk, V., Casanoves, F., Milchunas, D., et al. (2007). Plant trait responses to grazing – a global synthesis. *Global Change Biology , 13*, S. 313–341.

Diaz, S., Noy-Meir, I., & Cabido, M. (2001). Can grazing response of herbaceous plants be predicted from simple vegetative traits? (B. E. Society, Hrsg.) *Journal of Applies Ecology , 38*, S. 497-508.

Dradu, E., & Harrington, G. (January 1972). Seasonal crude protein content of samples obtained from a tropical range pasture using oesophageal fistulated steers. *Tropical Acriculture , 49* (1), S. 15-21.

Fallingrain.com. (03. 03 2008). *www.fallingrain.com*. Abgerufen am 03. 03 2008 von http://www.fallingrain.com/world/UG/52/Rushere.html

Fernandez-Ales, R., Laffarga, J., & Ortega, F. (1993). Strategies in Mediterranean grassland annuals in relation to stress and disturbance. (IAVS, Hrsg.) *Journal of Vegetation science , 4*, S. 313-322.

Foster, H. (1971). Rapid routine soil and plant analysis without automatic equipment. 1. Routine soil analysis. *E.Afr.agric.For.J.* (37).

Friedel, M. (1997). Discontinuous change in arid woodland and grassland vegetation along gradients of cattle grazing in central Australia. *Journal of arid environments , 37*, S. 145-164.

Friedel, M., Bastin, G., & Griffin, G. (1988). Range assessment and monitoring in arid lands: the derivation of functional groups to simplify vegetation data. *Journal of Environmental Management , 27*, S. 85-97.

Fuller, M. (2004). *The encyclopedia of farm animal nutrition.* Oxon; Camebridge, UK; USA: CABI Publishing.

Garnier, E. (1992). Growth analysis of congeneric annual and perennial grass species. *Journal of Ecology , 80*, S. 665-675.

Gaucherand, S., & Lavorel, S. (2007). New Method for rapid assesment of functional compositon of herbaceous plant communities. (E. S. Australia, Hrsg.) *Austral Ecology , 32*, S. 927-936.

Grimaud, S., Sserunjogi, M., Wesuta, M., Grillet, N., Kato, M., & Faye, B. (2006). Effects of season and agro-ecological zone on the microbial quality of raw milk along the various levels of the value chain in Uganda. *Trop Anim Health Prod* .

Grime, J. (1977). Evidence for the existence of three primary strategies in plants and it´s relevance to ecological and evolutionary theory. *Am.Nat. , 111*, S. 1169-1194.

Hadar, L., Noy-Meir, I., & Perevolotsky, A. (1999). The effect of shrub clearing and grazing on the composition of a mediterranea plant community: functional groups versus species. *Journal of Vegetation Science , 10*, S. 673-682.

Harker, K. (1959). An Acacia Weed of Uganda Grasslands. *Tropical Agriculture Trinidad* (Volume 36), S. 45-51.

Harrington, G. (1974). Fire effects on a Ugandan Savannah. *Tropical Grasslands* .

Harrington, G., & Thornton, D. (1969). A comparison of controlled grazing and manual hoeing as a means of reducing the incidence of Cymbopogon afronadus Stapf. in Ankole pastures, Uganda. *E. Afr. Agric. For. J. , 35* (2), S. 154-159.

Hodgkinson, K. (1992). Elements of grazing strategies for perennial grass management in rangelands. In G. Chapman, *Desertified grasslands: Their biology and management* (S. 77-94). London, United Kingdom: Academic Press.

Hodgson, J. (1979). Nomenclatur and definitions in grazing studies. *Grass Forage Science , 34*, S. 11-18.

Hodgson, J., & Illius, A. (1996). *The ecology and management of grazing systems.* Oxon: CAB International.

Horrell, C., & Tilney, G. (1970). Grassland. In J. Jameson, *Agriculture in Uganda* (second edition Ausg., S. 318-332). London, Great Britain: Oxford University Press.

Jackson, J., & Ash, A. (2001). The role of trees in enhancing soil nutrient availability for native perennial grasses in open eucalypt woodlands of north-east Queensland. (C. a. Science, Hrsg.) *Australian Journal of Agricultural Research , 52*, S. 377–386.

Jameson, J. (1970). *Agriculture in Uganda.* London: Oxford University Press.

Jameson, J., Rose, W., & Williams, E. (1970). Introduction and Organization. In J. Jameson, & J. Jameson (Hrsg.), *Agriculture in Uganda* (Second Edition Ausg., S. 1-11). London, Great Britain: Oxford University Press.

Juarez Lagunes, F., Fox, D., Blake, R., & Pell, A. (1999). Evaluation of Tropical Grasses for Milk Production by Dual-Purpose Cows in Tropical Mexico. *Journal of dairy science , 82* (2), S. 2136-2145.

Juko, C., & Brendon, R. (1961). The chemical composition of leaves and whole plants as an indicator of the range of availiable nutrients for selective grazing by cattle. *Tropical Agriculture , 38* (3), S. 179-187.

Kagoda, W. (2001). *Special project report: Effect of season on dry matter production and chemical composition of pastures on selected farms in Mbarara and Kabale districts of Uganda.* Makerere University, Kampala, Uganda.

Kahangire, P., & Lubanga, R. (2001). Water. In J. K. Mukiibi, *Agriculture in Uganda - Volume I: General Information* (S. 136-144). Kampala, Uganda: Fountain Publishers Ltd.

Kazi-Aoual, F., Hitier, S., Sabatier, R., & Lebreton, J. (1995). Refined approximations to permutation tests for mulitivariate inference. *Comp.Stat.Data Anal. , 20*, S. 643-656.

Kleyer, M. (1999). Distribution of plant functional types along gradients of disturbance intensity and resource supply in an agricultural landscape. (IAVS, Hrsg.) *Journal of Vegetation Science , 10*, S. 697-708.

Komutunga, E., & Musiitwa, F. (2001). Climate. In J. K. Mukiibi, *Agriculture in Uganda - Volume I: General Information* (S. 21-32). Kampala, Uganda: Fountain Publishers Ltd.

Landsberg, J., Lavorel, S., & Stol, J. (1999). Grazing response groups among understorey plants in ardi rangelands. (IAVS, Hrsg.) *Journal of Vegetation Science , 10*, S. 683-696.

Langdale-Brown, I. (1970). Vegetation. In J. Jameson, *Agriculture in Uganda* (second edition Ausg., S. 90-97). London, Great Britain: Oxford University Press.

Lavorel, S., Grigulis, K., McIntyre, S., Williams, N. S., Garden, D., Dorrough, J., et al. (2007). Assessing functional diversity in the field - methodology matters. *Functional Ecology* , S. 1-14.

Lavorel, S., McIntyre, S., & Grigulis, K. (1999). Plant response to disturbance in a Mediterranean grassland: how many functional groups? (IAVS, Hrsg.) *Journal of Vegetation Science , 10*, S. 661-672.

Lavorel, S., Rochette, C., & Lebreton, J.-D. (1999b). Functional groups for response to disturbance in Mediterranean old fields. *Oikos , 84*, S. 480-498.

Lavorel, S., Touzard, B., Lebreton, J.-D., & Clement, B. (1998). Identifying functional groups for response to disturbance in abandoned pasture. *Acta Oecol. , 19*, S. 227-240.

Leishman, M., Westoby, M., & Jurado, E. (1995). Correlates of seed size variation: a comparison among five temperate floras. *Journal of Ecology , 83*, S. 517-530.

Leng, R. (1997). *Tree foliage in ruminant nutrition.* Rome: FAO.

Long, M., Thornton, D., & Marshall, B. (1969). Nutritive Value of Grasses in Ankole and The Queen Elizabeth National Park, Uganda, II- Crude Protein, Crude Fibre and Soil Nitrogen. *Tropical Agriculture , 46* (1), S. 31-42.

MAAIF. (1997). *Meas Production Master Plan Studie.* Entebbe, Uganda: Ministry of Agriculture, Animal Industry and Fisheries (MAAIF).

Mahadevan, P., & Parsons, D. (1970). Livestock. In J. Jameson, *Agriculture in Uganda* (S. 333-344). London, Great Britain: Oxford University Press.

Mapinduzi, A. L., Gufu, O., Weladji, R. B., & Colman, J. E. (2003). Use of indigenous ecological knowledge of the Maasai pastoralists for assessing rangeland biodiversity in Tanzania. *African Journal of Ecology , 41*, S. 329-336.

Mazer, S. (1989). Ecological, taxonomic and life history correlates of seed mass among Indiana dune angionsperms. *Ecol.Monogr. , 59*, S. 153-175.

McIntyre, S., & Lavorel, S. (1994). How environmental and disturbance factors influence species composition in temperate Australian grasslands. *Journal of Vegetation Science , 5*, S. 373-384.

McIntyre, S., & Lavorel, S. (2001). Livestock grazing in subtropical pastures: steps in the analysis of attribute response and plant functional types. (B. E. Society, Hrsg.) *Journal of Ecology , 89*, S. 209-226.

McIntyre, S., Lavorel, S., & Tremont, R. (1995). Plant life history attributes: their relationship to disturbance response in herbaceous vegetation. *Journal of Ecology , 83*, S. 31-44.

McIntyre, S., Lavorel, S., Landsberg, J., & Forbes, T. (1999). Disturbance response in vegetation - towards a global perspective on functional traits. (IAVS, Hrsg.) *Journal of Vegetation Science , 10*, S. 621-630.

Mihreteab, Y. (2000). *Chemical composition and in vitro organic matter digestibility of selected grasses, legumes and fodders.* Special project report, Makerere University, Kampala.

Milchunas, D., & Lauenroth, W. (1993). Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecol. Monogr. , 63*, S. 327-366.

Milchunas, D., & Laueroth, W. (1993). Quantitative effects of grazing on vegetatioin and soils over a global range of environments. *Ecol. Momogr. , 63*, S. 327-366.

Milchunas, D., & Noy-Meir, I. (2002). Grazing refuges, external avoidance of herbivory and plant. *OIKOS , 99*, S. 113–130.

Milchunas, D., Lauenroth, W., Chapman, P., & Kazempour, M. (1990). Community attributes along a pertubation gradient in a shortgrass steppe. *journal of Vegetation Science , 1*, S. 375-384.

Millbank, J. (1956). Nitrogenin tropical soils. *East African Agricultral Journal , 22*, S. 73-75.

Ministry of Agriculture and Fisheries, U. (1996). *Study Report on The Comparative Analysis of Cattle Management systems in Different Areas of Uganda.* n.n.: n.n.

Ministry of Financial Planning and Economic Development, U. (. (1997). *Statistical Abstract.* n.n.: n.n.

Ministry of Financial Planning and Economic Development, U. (. (1996). *Statistical Abstracts.* n.n.: n.n.

Minson, D. (1990). *Forage in ruminants.* San Diego, California, USA: Academic Press Inc.

Moles, A. T., & Westoby, M. (2000). Do small leaves expand faster than large leaves and do shorter expansion times reduce herbivore damage? *Oikos , 90*, S. 517-524.

Mugasi, S. (1996). *Report on the baseline survey of Kazo county, Mbarara District. Dryland Husbandry Project, Makerere Universtiy.* unpulished.

Mugerwa, J. (2001). Animal feed rsources. In J. K. Mikiibi, *Agriculture in Uganda - Volume IV: Livestock and Fisheries* (S. 196-236). Kampala, Uganda: Fountain Publishers Ltd.

Mukiibi, J. K. (2001). *Agriculture in Uganda - Volume I: General Information.* Kampala, Uganda: Fountain Publishers Ltd.

Mukiibi, J. K. (2001b). *Agriculture in Uganda - Volume IV: Livestock and Fisheries.* Kampala, Uganda: Fountain Publishers, Ltd.

Musiitwa, F., & Komutunga, E. (2001). Agricultural Systems. In J. K. Mukiibi, *Agriculture in Uganda - Volume I: General Information* (S. 220-230). Kampala, Uganda: Fountain Publishers Ltd.

Mwebaze, S. M. (28. 02 2008). *www.fao.org*. Abgerufen am 28. 02 2008 von Food and agricultural Organisation: http://www.fao.org/ag/AGP/AGPC/doc/Counprof/uganda/uganda.htm#5.%20PASTURE

Norton, B. (1981). Differences between species in forage quality. In T. Hacker, *Nutritional limits to Animal Production from Pastures* (S. 89-110). Farnham Royal, United Kingdom: Commonwealth Agricultrue Bureaux.

Noy-Meir, I., Gutman, M., & Kaplan, Y. (1989). Responses of mediterranean grassland plants to grazing and protection. *Jourlna of Ecology , 77*, S. 290-310.

OED. (1998). *The New Oxford Dictionary of English.* (P. Hanks, & J. Pearsall, Hrsg.) Oxford England: Oxford University Press.

Okello, S. S. (2006). Milk production of indigenous Ankole cattle in Uganda as influenced by seasonal variations in temperature, rainfall and feed quality. *Makerere University Research Journal* , S. 73–92.

Oryokot, J. (2001). Weeds. In J. K. Mukiibi, *Agriculture in Uganda- Volume I: General Information* (S. 419-449). Kampala, Uganda: Fountain Publishers Ltd.

Parsons, D. (1970). Agricultural Systems. In J. Jameson, *Agriculture in Uganda* (second edition Ausg., S. 297-319). London, Great Britain: Oxford University Press.

Parsons, D. (1960). *The systems of agricultural practised in Uganda. Plantain-Robusta coffee system No. 2 and Pastoral systems No. 5.* n.n.: n.n.

Pihlgren, A., & Lennartsson, T. (2008). Shrub effects on herbs and grasses in semi-natural grasslands: positive, negative or neutral relationships? *Grass and Forage Science , 63*, S. 9–21.

Raunkiaer, C. (1934). *The life forms of the plants and statistical plant geography.* Oxford: Clarendon Press.

Rebollo, S., Milchunas, D., Noy-Meier, I., & Chapman, P. (2002). The role of a spiny plant refuge in structuring grazed shortgrasse steppe plant communities. *Oikos , 98*, S. 53-67.

Rubanza, C., Shem, M., Bakengesa, S., Ichinohe, T., & Fujihara, T. (December 2005). Content of macro and micro minerals of deferred forages in silvo-pastoral traditional fodder banks (Ngitiri) of Meatu district of central north-western Tanzania. *Livestock Research for Rural Development , 17* (12), S. s.p.

Sabiiti, E. (2001). Pastures and range management. In J. K. Mukiibi, *Agriculture in Uganda - Volume IV. Livestock and Fisheries* (S. 237-288). Kampala, Uganda: Fountain Publishers Ltd.

Sabiiti, E., & Wein, R. (1991). Effects of fire intensity and browsing by goats in the dynamics of Acacia encroachment in rangelands of Uganda. *Proceedings of the 4th International Range Congress. Volume II*, S. 860-862. n.n: n.n.

Sabiiti, E., & Wein, R. (1987). Fire and Acacia seeds: A Hypothesis of Colonization Success. *Journal of Ecology* (74), S. 937-946.

Scholes, R., & Walker, B. (1993). *An African savanna: synthesis of the Nylsvley study.* Cambridge University Press.

Silanikove, N. (2000). Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livestock Production Science , 67*, S. 1–18.

Ssali, H. (2001). Soil fertility. In J. K. Mukiibi, *Agriculture in Uganda - Volume I: General Information* (S. 104-134). Kampala, Uganda: Fountain Publishers Ltd.

Tangeo.com. (03. 03 2008). *www.tangeo.com*. Abgerufen am 03. 03 2008 von http://www.tageo.com/index-e-ug-v-52-d-m2430640.htm

Tilney, G. (1970). Weeds. In J. Jameson, *Agriculture in Uganda* (second edition Ausg., S. 297-317). London, Great Britain: Oxford University Press.

Turner, I. (1994). A qantitative analysis of leaf form in woody plants from the world´s major broadleaved forest types. *J. Biogeogr. , 21*, S. 413-419.

Twinamasiko, N. (2001). Dairy Production. In J. K. Mukiibi, *Agriculture in Uganda - Volume IV: Livestock and Fisheries* (S. 18-42). Kampala, Uganda: Fountain Publishers Ltd.

USDA, N. (13. 2 2009). *The PLANTS Database*. (N. P. Center, Herausgeber) Abgerufen am 13. 2 2009 von plants.usda.gov: http://plants.usda.gov

Valtorta, S., Leva, P., & Gallardo, M. (1997). Evaluation of different shades to improve dairy cattle well-being in Argentina. *Int J Biometeorol , 41*, S. 65–67.

van Groenendahl, J., Klimes, L., Klimesova, J., & Henrdiks, R. (1997). Comparative ecology of clonal plants. In J. Harper, J. Silvertown, & M. Franco, *Plant life histories* (S. 191-209). Cambridge: Cambridge University Press.

Waigambi, M. (1993). *Special Project Report on Pasture Management and Utilisation on selected Farms in Pallisa sistrict.* n.n.: n.n.

Weiher, E., van der Werf, A., Thompson, K., Roderick, M., Garnier, E., & Eriksson, O. (1999). Challenging Theophrastus: A common core list of plant traits for functional ecology. *Journal for Vegetation Science , 10*, S. 609-620.

Westoby, M. (1998). A leaf-height-seeds (LHS) plant ecology strategy scheme. *Plant Soil* (199), S. 213-227.

Wheaton, T. (1994). Plants of the Northern Australian rangelans. *National Landcare Program; Meat Research Corporation* . Darwin, Australia: NT Department of Lands, Housing and Local Government.

Wienmann, W. (1955). *The Grasses and Pastures of South Africa.* Cape Town, South Africa: Central News Agency.

Wilson, J. (1962). The vegetation of Karamoja district, Northern Province of uganda. In n.n., *Mems. Res. Div. Dep. Agric. Uganda.* Uganda.

9. Index of figures

10. Index of tables

11. Appendix

9.1. Glossary

This chapter defines terms used in course of this thesis. The terms appear in alphabetical order for more convenience.

Biological trait

A biological trait is defined as a measurable, phenotypic characteristic for which relationships with biological function have been described (Gaucherand & Lavorel, 2007).

Forb

The OED (1998) defines a herbaceous flowering plant other than a grass. Cornelissen et al. (2003b) define forbes as broad leaved herbaceous plants. Equivalently for the term “forb” the term “herb” will be used in this work.

Functional trait-based approach

This approach was developed in ecology to characterize natural grasslands through attributes of dominant species. It should provide in a first stage a characterization of factors acting on vegetation and then an evaluation of its use value (Ansquer et al., 2004).

Ley

A piece of land put down to grass, clover, etc., for a single season or a limited number of years, in contrast to permanent pasture. (OED 1998).

Leaf width

Widest point of the last grown, fully matured leaf.

Leaf length

Longest distance from leaf base to leaf tip of the last grown, fully matured leaf.

Peduncle

A peduncle is the stalk bearing a flower or fruit, or the main stalk of an inflorescence (OED, 1998).

Plant (functional) trait

Biological traits are measurable phenotypic characteristics for which relationships with biological function have been described, provide the basis of the functional classification (Gaucherand & Lavorel, 2007). According to literature (plant) functional traits are characteristics, that inform on the functioning of plants and, by extension, on vegetation a species belongs to (Ansquer et al., 2004). The technique focuses on biological traits of plant communities in each pasture. For this work plant traits recorded have been selected according to the research questions. Plant functional trait, plant trait and trait are to be synonimously understood understood in this thesis.

Plant functional type

Plant functional types and plant strategies can be defined as groups of plant species sharing similar functioning at the organism level, similar responses to environmental factors and/or similar roles in (or effects on) ecosystem biomes. This similarities are based on the fact, that they tend to share a set of key functional traits (Cornelissen et al., 2003b, Lavorel & Garnier 2002).

Plant height

Distance from ground level to the furthest tip of vegetative, photosynthetic tissue.

Plasticity

Plasticity may be defined as the ability to alter allocation patterns, morphology or physiology in response to environmental variation (Cornlissen et al 2003).

Ramet

The ramet is the recognisable, separate, above ground unit of a plant (Cornlissen et al 2003b). Weiher et al. (1999) define a ramet as an iteration of the basic form of the plant without obvious connections to other ramets, that would clearly unify the parts into one iteration.

Reproductive height:

Distance from ground level to the tip of the longest reproductive plant part.

Scape

A leafless and flowerless stalk (Cole, 2008).

Transect round

Expression used in this thesis to describe 1 of the 2 time periods, during which data collection in the field has taken place.

Trait transect

The technique used for the collection of plant functional traits. The method described in aucherand & Lavorel (2007) has been used. Transect is also used synonymously to trait transect.

9.2. Questionnaire on pasture management

Date: .... Research Area: Mbarara ☐ Rushere ☐

Name of farmer:..

Questions concerning overall pasture yield and quality:

How many paddocks/grazing areas do you have?..

How high do you estimate the **percentage** of **low/medium/high yielding** pastures on your farm? (percentage of the whole pasture area)

Low (1):.................................medium(2):................................high(3):......................................

How high do you estimate the **percentage** of **low/medium/high quality** pasture on your farm? (percentage of the whole pasture area)

Low(1):.................................medium(2):................................high(3):......................................

paddock specific questions:

paddock 1:

Number of paddock/all paddock analysed: ___________/40 (2 per farm on 20 farms)

Name of paddock?..

Size of paddock?...

How many days with rain have you had so far? ....

First/second transect round: first ☐ second ☐

Which herd is usually grazing on this pasture? Ankole ☐

Crossbred ☐

Do you also keep the other herd on this paddock? yes ☐ no ☐

If herd is currently on paddock:

How long has the herd already been on this paddock?..............................

How much time is there in between keeping the herd on this paddock?..............................

If herd is currently NOT on plot:

When was the paddock grazed last?..............................

How much time is there in between keeping the herd on this paddock?..............................

How you judge the quality of this paddock? low ☐ medium ☐ high ☐

How do you judge the paddock yield? low ☐ medium ☐ high ☐

Do you have problems with erosion on this paddock? yes ☐ no ☐

Has erosion: increased ☐ decreased ☐ same ☐

What kind of erosion problems do you have here?

wind ☐ water ☐

other ☐ not known ☐

Is this paddock especially suitable for this herd? yes ☐ no ☐

Why is it especially suitable? ....

....

Do you do any kind of pasture management? yes ☐ no ☐

What kind of pasture management do you do?

Bush clearing ☐ burning ☐ sowing ☐ drainage ☐ other:..............................

paddock 2:

Number of paddock/all paddock analysed: ___________/40 (2 per farm on 20 farms)

Name of paddock?..............................

Size of paddock?..............................

How many days with rain have you had so far? ....

First/second transect round: first ☐ second ☐

Which herd is usually grazing on this pasture? Ankole ☐

Crossbred ☐

Do you also keep the other herd on this paddock? yes ☐ no ☐

If herd is currently on paddock:

How long has the herd already been on this paddock?..............................

How much time is there in between keeping the herd on this paddock?..............................

If herd is currently NOT on plot:

When was the paddock grazed last?..............................

How much time is there in between keeping the herd on this paddock?..............................

How you judge the quality of this paddock? low ☐ medium ☐ high ☐

How do you judge the paddock yield? low ☐ medium ☐ high ☐

Do you have problems with erosion on this paddock? yes ☐ no ☐

Has erosion: increased ☐ decreased ☐ same ☐

What kind of erosion problems do you have here?

wind ☐ water ☐

other ☐ not known☐

Is this paddock especially suitable for this herd? yes ☐ no ☐

Why is it especially suitable? ....

....

Do you do any kind of pasture management? yes ☐ no ☐

What kind of pasture management do you do?

Bush clearing ☐ burning ☐ sowing ☐ drainage ☐ other:..

9.3. Questionnaire on pasture vegetation

Date: .... Research Area: Mbarara ☐ Rushere ☐

Name of farmer:..

A)For the whole Farm:

1) Name three good plants on your pastures and what is good about them:

2) Name three bad plants on your pastures and what is bad about them:

3a) Have any plants on the pastures disappeared or become much less in the last 10 years?
☐ yes ☐ no

3b) If, yes which plants?..

4a) Did you notice any plants on the pastures in the last 10 years that have not been here before?
☐ yes ☐ no

4b) If yes, which plants:

5) How many days of rain have you had since this rainy season started?...................................

B) Crossbred pastures:

6) Since when do you graze only crossbreds on these pastures?

7) Has the number of bushes/shrubs in the crossbred pastures increased or decreased in the last 10 years?
☐ increased (if yes proceed to question 8) ☐ decreased (proceed to question 9)

8) If the number of bushes has increased on the crossbred pasture, by how much?
☐ to a lesser extent: does not influence quality of the pasture
☐ moderate: acceptable level, but many parts of the pasture effected
☐ a lot: it has a negative impact on the pasture

9) Has the number of trees in the crossbred pastures increased or decreased in the last ten years?
☐ increased (if yes proceed to question 10) ☐ decreased (proceed to question 11)

10) If the number of trees has increased on the crossbred pasture, by how much?
☐ to a lesser extent: does not influence quality of the pasture
☐ moderate: acceptable level, but many parts of the pasture effected
☐ a lot: it has a negative impact on the pasture

11) If the number of trees has decreased, why?

12) What are the plants that cause most problems on the crossbred pasture? Please tell what problems these plants cause and why if you know?

13) Are there plants on the crossbred pastures that are not on Ankole pastures? If yes which plants?

C) Ankole pastures:
14) Since when do you graze only Ankole on these pastures?

15) Has the number of bushes/shrubs in the Ankole pastures increased or decreased in the last 10 years?
☐ increased (if yes proceed to question 16) ☐ decreased (proceed to question 17)

16) If the number of bushes has increased on the Ankole pasture, by how much?

☐ to a lesser extent: does not influence quality of the pasture
☐ moderate: acceptable level, but many parts of the pasture effected
☐ a lot: it has a negative impact on the pasture

17) Has the number of trees on the Ankole pastures increased or decreased in the last ten years?
☐ increased (if yes proceed to question 18) ☐ decreased (proceed to question 19)

18) If the number of trees has increased on the Ankole pasture, by how much?
☐ to a lesser extent: does not influence quality of the pasture
☐ moderate: acceptable level, but many parts of the pasture effected
☐ a lot: it has a negative impact on the pasture

19) If the number of trees on the Ankole pastures has decreased, why?

20) What are the plants that cause most problems on the Ankole pastures? Please tell what problems these plants cause and why if you know?

21) Are there plants on the Ankole pastures that are not on crossbred pastures? If yes which plants?

9.4. Protocol for measurements of traits

Plant height

How to record

Measure the distance between the highest photosynthetic tissue in the canopy and ground level (Cornelissen et al., 2003b).

Reproductive height

How to record

Measure the height of the highest reproductive organ.

Leaf width

How to record

Measure last full grown leaf of a plant at its widest point.

Leave length

How to record

Measure last full grown leaf of a plant at its longest point.

Growth form

How to record

Growth form is a categorical trait and it is assessed through straightforward field observation. There are 20 categories of growth forms to which plants found are assigned (Cornelissen et al., 2003b).

Growth form categories (Cornelissen et al., 2003b)

Growth form	**description**
Short basal	Leaves < 0.5m long concentrated very close to soil surface, e.g. rosette plants or prostrate growth forms
Long basal	Leaves Large (petioles) > 0.5m long, emerging from the soil surface but not forming tussocks
Semi basal	Significant leaf area deployed both close to the soil surface and higher up the plant
Erect leafy	Plant essentially erect, leaves concentrated in middle or top parts
Cushions (=pulvinate)	Tightly packed foliage held close to the soil surface with relatively even and rounded canopy boundary
Tussocks	Many leaves from basal meristems forming prominent tufts
Dwarf shrubs	Woody plants up to 0.8m tall
Shrubs	Woody plants with main canopy deployed relatively close to the soil surface on one or more relatively short trunks
Trees	Woody plants with main canopy elevated on a substantial trunk
Leafless shrubs or trees	With green, non-succulent stems as the main photosynthetic structures.
Short succulents	Plant height > 0.5m, green globular or prostrate "stems" with minor or no leaves
Tall succulents	Plant height >0.5m, green column "stems" with minor of no leaves
Palmoids	Plants with a rosette of leaves at the top of a stem
Epiphytes	Plants growing on the trunk or in the canopy of shrubs or trees (or telegraph wires)
Climbers and Scramblers	Plants that root in the soil and use external support for growth and leaf positioning, this group includes lianas
Hemi-Epiphytes	Plants that germinate in other plants and then establish their roots in the ground or plants that germinate on the ground, grow up the tree and disconnect their soil contact. This group also includes tropical stranglers (e.g. some figs)
Hemiparasites or holoparasites	With haustoria tapping into the branches of shrubs or trees to support green foliage (e.g. mistletoes)
Aquatic submerged	All leaves submerged in water
Aquatic floating	most of the leaves floating on water
Other growth forms	A brief description is to be given

Note: Growth forms 1-6, 18 and 19 are always herbaceous (Cornelissen, et al., 2003).

Clonality

How to record

Observation in the field

Categories:

0 = no clonality→ no ability of plant to reproduce itself vegetatively.

1 = stolons: horizontal stems

2 = gemmiparous: adventitious buds on leaves

3 = other vegetative buds or plant fragments can disperse and produce new plants. This category includes:

Pseudovivipary: vegetative propagules in the inflorescence

Gemmipary: adventitious buds on leaves

Spinescence

How to record

Spines, thorns and prickles are summarized as “spine equivalents”. Only those on vegetative plant parts (e.g. stems, leaves) are considered. Spine equivalents are defined as “soft” if, when mature, they can be easily bent by pressing sideways with a finger. Assign to one of 5 classes:

0 = no spines, thorns or prickles

1 = low or very local density of soft spine equivalents < 5mm; plant may sting or prickle a little, when hit carelessly

2 = high density of soft spine equivalents, intermediate density of spine equivalents of intermediate hardness or low density of spine equivalents of hard, sharp spine equivalents > 5mm; plant hurts when hit carelessly

3 = intermediate or high density of hard, sharp spine equivalents > 5mm; plant hurts a lot when hit carelessly

4 = Intermediate or high density of hard, sharp spine equivalents > 20mm; plant may cause significant wounds when hit carelessly

5 = Intermediate or high density of hard, sharp spine equivalents > 100mm; plant is dangerous to careless large mammals including humans.

9.5. Modified plant identification and farmers´ classification:

date:.............................. farmer:..farmnumber: .

breed	local plant name	English plant name	scientific plant name	plant quality good/ bad/ neutral	Why is the plant good/bad/neutral? (DETAILS!)

9.6. Pasture productivity data sheet - fresh pasture matter

date	farm number	paddock number	breed, a = Ankole; c=cross bred	transect round	transect	sample number	weight, kg	weight without bag (0.017kg)
dd.mm. yyyy				1 = round 1 2 = round 2				