

**EMPIRICAL VERIFICATION OF LOCAL KNOWLEDGE IN THE
DESCRIPTION OF NUTRITIVE VALUE OF FORAGES IN MIXED
FARMING SYSTEMS OF TURIANI, MOROGORO, TANZANIA**



**FOR REFERENCE
ONLY**

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THE DEGREE OF DOCTOR OF PHILOSOPHY OF SOKOINE
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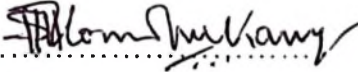
ABSTRACT

Studies were conducted in the mixed farming system of Turiani division, Morogoro, Tanzania in order to find out how local knowledge (LK) characterizes different types of forages, feeding and production responses of crossbred cattle as well as to understand how nutritive value of forages defined by LK compares with formal scientific knowledge. Participatory rural appraisals (PRA), cross-sectional and longitudinal surveys and controlled animal experiments were undertaken. The cross-sectional survey covered 125 households. In the longitudinal survey, 30 respondents were individually interviewed for four consecutive times within intervals of two months. Feed preference experiments were carried out with four intact male crossbred calves whereby green grasses were provided either singly [*Panicum maximum*, *Panicum trichocladum*, *Pennisetum purpureum* and *Rottboelia cochinchinensis*] or in combinations of two forages in equal proportions [*P. maximum* + *P. trichocladum*; *P. maximum* + *R. cochinchinensis*; *P. trichocladum* + *R. cochinchinensis* and *P. purpureum* + *P. trichocladum*] for four consecutive days. Calves were simultaneously observed while each animal was feeding on one of the four treatments in sequential periods of 15 minutes each in four random orders (1, 2, 3 and 4) every test-day. Amounts of herbage eaten and numbers of prehension bites were recorded. The bite rate, bite mass and intake rate were calculated. In another experiment, five bull calves were allocated to each of the four treatments; [*P. maximum* (plus concentrate supplement); *P. maximum* + *P. trichocladum* (in 5:1 ratio) (plus concentrate supplement); *P. maximum* (without supplement) and *P. maximum* + *P. trichocladum* (in 5:1 ratio) (without supplement)] in a completely

randomised design. Dry matter intake (DMI) and growth performance of calves similar to those used in the preference study were determined including economic analysis of the above practices. The surveys revealed that criteria for forage quality include preference by animals, high milk yield, fast stomach fill, availability, absence of feeding disorders, high milk quality, health condition of animals and convenience in cut and carry. Logistic regression analysis showed that forage preference by cattle ranked (in descending order) *Digitaria* spp, *P. purpureum*, *T. laxum*, *P. trichocladum*, *Cynodon* spp and *R. cochinchinensis* with *P. maximum* serving as a reference grass forage. However, *P. purpureum* and *T. laxum* ranked first and second respectively for criteria of high milk yield, fast stomach fill, improving health condition and convenience at harvesting whereas *M. pruriens* was the species most preferred by cattle followed by *V. pubescens*, *I. aquatica* and *C. africana* when the legumes and forbs were compared against *M. atropurpureum*. The intake rate of *P. purpureum* of 15.72gDM/min, bite rate of 5.31bites/min and bite mass of 3.11g/bite respectively was significantly higher ($P < 0.05$) than that of other single grass species tested. Total DMI of *P. trichocladum* + *R. cochinchinensis* and *P. purpureum* + *P. trichocladum* of 224.54g/15min and 232.52g/15min were significantly ($P < 0.05$) higher than that of *P. maximum* + *P. trichocladum* and *P. maximum* + *R. cochinchinensis* respectively. Supplementation increased total DMI of grass forages regardless of whether they were mixed or not. It is concluded that LK and formal scientific knowledge of forage quality description have social, economic and biological justifications that may be similar or different. However, more studies are needed in LK and complementary knowledge systems for sustainable utilization of feeds and other resources abundant in smallholder settings.

DECLARATION

I, DANIEL MUSHUMBUSI KOMWIHANGILO, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my original work and has never been submitted for a degree award in any other University.

Signature 

Date.....15/07/2005

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DEDICATION

To East African smallholder farmers from whom I am rooted; and to all those who diligently labour for sustainable development of mixed production systems.

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LIST OF ABBREVIATIONS AND SYMBOLS

ADF	-	Acid detergent fibre
AOAC	-	Association of Official Analytical Chemists
cm	-	centimetre
CF	-	Crude fibre
CP	-	Crude protein (N x 6.25)
°C	-	Degree Celsius
d	-	Day
DANIDA	-	Danish International Development Agency
DASP	-	Department of Animal Science and Production
DIAS	-	Danish Institute of Agricultural Science
DM	-	Dry matter
DMI	-	Dry matter intake
DOMD	-	Digestible organic matter in the dry matter
E	-	East (of Greenwich)
ED	-	Effective degradability
EE	-	Ether extract
ENRECA	-	Enhancement of research capacity
FAO	-	Food and Agriculture Organisation of the United Nations
FCR	-	Feed conversion ratio
FS	-	Farming system
FSA	-	Farming Systems Approach
FSR	-	Farming System Research

g	-	Gram
GDP	-	Gross domestic product
GIS	-	Geographical information system
GPS	-	Geographical positioning system
h	-	hour
ha	-	Hectare
IK	-	Indigenous knowledge
IVDMD	-	<i>In vitro</i> dry matter digestibility
IVOMD	-	<i>In vitro</i> organic matter digestibility
kg	-	Kilogram
RAVU	-	Royal Agricultural and Veterinary University, Denmark
LPRI	-	Livestock Production Research Institute
LK	-	Local knowledge
LKS	-	Local knowledge system
LSMeans	-	Least Square means
LW	-	Live weight
LW kg ^{0.75}	-	Metabolic body weight in kg
m.a.s.l	-	Metres above sea level
ME	-	Metabolizable energy
MSE	-	Mtibwa Sugar Estates
MJ	-	Megajoule
N	-	Nitrogen
NDF	-	Neutral detergent fibre
NFE	-	Nitrogen free extract

CHAPTER ONE

1.0 INTRODUCTION

1.1 General

Improved technologies in agriculture have been a catalyst for increased production per unit of land or livestock in developed countries. The impact of these technologies has, however, not been substantial to the agricultural development in many developing countries of Sub-Saharan Africa, Asia and Latin America (Bechstedt, 1996; Ayalew *et al.*, 2003). Douthwaite *et al.* (2003) asserted that the linear transfer of technology (TOT) model that was considered appropriate for agricultural revolution in some areas was not uniformly feasible because of a variety of reasons including variable and harsh weather, changing economic activities or dynamic land use changes that prevail in smallholder settings of the developing countries. Norman *et al.* (1994) and Bechstedt (1996) consider that disparity in agricultural development could be due to the fact that development agencies, policy makers and even research scientists tend to neglect factors that hold the integrity of farming systems in developing countries. However, Niamir (1990), Thorne *et al.* (1999) and Bebe *et al.* (2003a,b) contend that pastoralists and smallholder farmers in developing countries have multiple objectives in their production circles, centred on their local understanding of ecosystems and production systems.

Of recent, therefore, there has been an increasing awareness of a need for integrating local knowledge (LK) or indigenous knowledge (IK) with modern and more formal technologies (Walker *et al.*, 1999; Nuwanyakpa *et al.* 2000). The emphasis has been on building on what the farmers already know and that there is a need for recognising and acknowledging farmers' role in technology development (Haverkort, 1996). Thus, it is now believed that the integration of local or indigenous knowledge into more formal knowledge systems might lead to sustainable development initiatives (including agricultural development), and could contribute towards alleviating and / or eradicating poverty among the rural population (World Bank, 2000). In other words, it is envisaged that effective and sustainable rural development could be achieved through combined efforts of local communities and external agencies (be it governmental and non governmental organisations); basing on local participation in identifying, planning, managing and utilizing the vast biological, physical, human or intellectual resources at hand.

In the view of the participatory paradigms, therefore, different approaches and methodologies have been proposed in order to understand farmers' needs and aspirations surrounding their agricultural activities. The farming systems approach has been suggested (Norman *et al.*, 1994) to offer opportunities for smallholder farmers, extension agents and research scientists to exchange information and ideas and set goals for further action. Moreover, Thapa *et al.* (1995) argued that if used effectively, this holistic and participatory approach could generate useful information from farmers about livestock feeds and other resources. The generated information

could then be linked or modified by other formal scientific methods for more profitable agricultural production systems.

Earlier studies conducted in East Africa by anthropologists and social historians demonstrated the application of LK in shifting cultivation, irrigation, mountain farming, intensive livestock systems as well as in pastoral and other traditional livestock systems (McCall, 1996). Nevertheless, it was asserted that the past studies on LK were deficient due to lack of emphasis on technical details and most of these were more general and focused on individual producers. Therefore, more studies on local knowledge systems (LKS) that link the community in exploiting specific resources were advocated and some have been undertaken in Tanzania and in other countries. These include studies on soil quality in the eroded hills of Kondoa Irangi in Tanzania (Kangalawe, 2001) and tree forage nutrition in the mid hills of Nepal (Thorne *et al.*, 1999). These studies and those of Kajembe (1994), Magayane (1995) and more recently that of Larsen (2000) have demonstrated intrinsic linkages of LK and formal sciences in areas of soil, agro-forestry and natural resource management.

Despite the commendable efforts on ascertaining the role of IK, LK or LKS in the life of the people and its usefulness for advancement of other knowledge systems, there remains a lot to be done with respect to understanding the utility of LK in livestock production. The urgent need is felt, especially, on how different knowledge systems could enrich one another in aspects of livestock feeds and feeding. The ultimate goal of this is improved livelihoods of the majority of rural farmers and for

the sustainability of tropical / smallholder livestock production systems as a whole (Spedding, 1995).

1.2 Justification and scope of the study

The smallholder dairy systems are livestock production systems in which milk is intended for sale. Depending on agro-ecological zonation, the cattle production component is integrated with other classes of livestock such as goats, pigs and poultry and crops such as maize, beans, rice, bananas and coffee (Otte and Chilonda, 2003). The smallholder farmers who operate in the dairy enterprises are obviously acquainted with the macro- and microenvironments related to crop, livestock and other economic and social activities.

In this thesis, a sugarcane-paddy-dairy (SPD) farming system was designated based on the major cash crop, food/cash crop and dairy cattle components produced by smallholder farmers in the study area. In executing their obligations, farmers are always confronted with priorities and preferences. Observation had indicated, for example, that in the management of exogenous and indigenous forage resources a decision to feed any of the forage species from what could be available was not done profusely but under preconceived ideals of smallholder farmers (Komwihangilo *et al.*, 2001). At the same time, there is little or no effort of deliberate management (such as establishment) of the commonly used materials in some of the smallholder production systems. In such cases, therefore, there arose a need for a critical study of farmers' perspectives in the use of available forages. The systems approach to studies

of LK was considered as an appropriate entry point because LK could be applied in various areas of livestock management including feeding and conservation of grasses and other resources. In other words, LK had and still has an inevitable role to play in feeding and feed resource management and thus in enhancing performance of cattle and other types of livestock in mixed livestock production systems.

Therefore, informal and formal methodologies were applied to study LK of the nutritional qualities of forages. Similarly, it was the intention of the study to examine consistency of 'formal scientific understanding' *versus* 'local understanding' of forage qualities among the smallholder farmers. Thus the **broad objective** was to study the role of LK in feeding of local and improved cattle for sustainable productivity of the crop-livestock based production systems. The **specific objectives** of the work were:

1. To study the sugarcane-paddy-dairy (SPD) based farming system of Turiani division with respect to feeding of local and improved dairy cattle.
2. To study how LK is used to characterize different types of forages, feeding and production response of crossbred cattle.
3. To compare LK on nutritive value of forages with formal scientific knowledge as expressed through feed tables and feeding systems

1.3 Organisation of the thesis

The thesis is organised into five chapters. Chapter one gives a broad introduction to the study, reasons for undertaking it and the objectives that were to be met at the end of the study. Chapter two is a review of the current state of knowledge on key aspects underlying the study. These include definitions of key concepts underlying the study including indigenous knowledge, local knowledge, farming systems and nutritive value. Chapter three gives the conceptual framework, specific methods used in the study including data collection techniques and data analysis. Chapter four presents results and discussion of information obtained from farmers and from controlled experiments whereas chapter five gives conclusions and recommendations emanating from the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

This chapter reviews the current state of local and formal scientific knowledge with respect to livestock production and feed resource utilization in smallholder systems. In the early part of the chapter definitions of concepts of indigenous and local knowledge as well as the concepts of farming systems and farming systems approach (research) were revisited. This was followed by a review of pertinent farming systems of Tanzania in the context of the global farming systems classification. In the final parts of the chapter methods used in local knowledge studies and formal scientific methods that are used in the assessment of quality of forages were highlighted.

2.2 Concepts and definitions

2.2.1 Indigenous versus local knowledge

Knowledge held by farmers in different parts of the world has largely been distinguished as either *local* or *indigenous knowledge*. The International Plant Genetic Resources Institute (IPGRI, 2000) defined indigenous knowledge (IK) as *knowledge that develops in a particular area and accumulates over time through*

being handed down from generation to generation. The term 'IK' has been used synonymously with such terms as "local knowledge"(Niamir, 1990) "rural peoples knowledge", "local technology" (Bunders *et al.*, 1996) or "farmers knowledge" (Rutatora, 1995; ole Lengisugi, 1995; Ortiz, 1999; Kajembe *et al.*, 2000a). Every society or community has its own norms and practices. Therefore, for its survival it must embrace one form or another of IK. For instance, the Task Force on IK in Uganda (UNCST, 1999) argued that IK is part and parcel of community social order and is embedded in community practices and institutional relationships. Given this outlook, Rutatora (1995) noted four characteristics of IK:

- It is possessed by people in a particular environment, ethnic group or society;
- It comprises of cognition and techniques that evolve over time through people or practitioners living by results;
- It is ever changing;
- It borrows selectively from outside.

Sinclair and Joshi (2001) refer to IK as *local knowledge (LK)* that is unique to a culture or society. Niamir (1990) noted that despite embracing accumulated cultural knowledge, LK encompasses information that is modified through contacts with other cultures that enter the local community over time. van Vlaenderen (2000) regards the term LK as an umbrella of other terms, being a collection of ideas and assumptions of people that are used to guide, control and explain actions within a specific setting. But apart from above definitions, there has been a tendency of distinguishing IK or LK from 'formal scientific knowledge'. The latter has, therefore, been termed as 'global', 'international', 'western' knowledge or 'formal

science' (Agrawal, 1995). This is often generated through formal, public or private research institutions and universities.

According to Hillbur (1998) every knowledge system has its own epistemology i.e. its own theory of what knowledge is. As a result, interpretation of knowledge may depend on who does it and for what purpose. For example, the phrase like *local knowledge systems* (LKS) could be used in describing the human interactions with the environment and the derived knowledge of natural resource management (Larsen, 2000). This view about LKS and definitions of IK and LK reveal that different authors often use the terms IK, LK and LKS interchangeably. Thus in order to avoid ambiguity of terms in this thesis, the phrase '*local knowledge*' is used in the context of the definition of Sinclair and Joshi (2001) that *local knowledge* (LK) is *people's understanding about locally available resources (e.g. trees) and the environment derived through observation and experience*.

2.2.2 Nutritive value

The nutritive value of a diet is defined as a measure of its ability to maintain or promote growth or some other biological activity in animals (Blaxter, 1977). Meanwhile, the Medical Dictionary (2003) also defines nutritive value as an indication of the contribution of food to the nutrient content of the diet. The Medical Dictionary noted further that this value depends on the quantity of food, which is digested and absorbed. It also depends on the amounts of essential nutrients (protein, fat, carbohydrate, minerals and vitamins) that it contains (McDonald *et al.*, 1998;

Medical Dictionary, 2003). Although the physiological effects of a feed/diet could be felt after a long-term of feeding, Boumont *et al.* (2003) recognise that the nutritive value could, in a short term, affect intake and ingestibility of particular types of forage materials.

2.2.3 Farming systems and Farming systems research

There are different ways in which a farming system (FS) could be defined. According to Ringia (1993), a FS is a unique and reasonable stable arrangement of farming enterprises that a household manages according to well-defined practices in response to physical, biological and socio-economic factors; and in accordance with household goals, preferences and available resources. Similarly, the International Plant Genetic Resources Institute (IPGRI, 2000) defined FS as a combination of all elements of a farm, which interact as a system; including people, crops and other vegetation, livestock and wildlife as well as the environmental, social, economical and ecological interactions between them.

From the past few decades FS has been considered along with the concept of research (R) thus Farming Systems Research (FSR) (Norman *et al.*, 1994; IPGRI, 2000) or Farming Systems Research and Extension (FSR/E) (Ringia, 1993). The IPGRI (2000) defined FSR as *adaptive research in which multidisciplinary teams are involved to assess the technological needs of research domains and to target technology development to specific domains*. Nevertheless, other terms such as Participatory (People-centred) Technology Development (PTD) (Haverkort, 1996),

Farming Systems Approach (FSA) and On-farm Research with Farming Systems Perspective (OFR / FSP) (Kirway and Ulotu, 1997) are used synonymously with FSR or FSR/E. However, Norman *et al.* (1994) asserted that FSR/E is a research and extension approach which is focused at problem solving, is iterative in nature and that it puts emphasis on farmer participation and interdisciplinary team work in the course of technology development and dissemination. Ringia (1993) stressed further that FSR is considered as an approach to agricultural research that not only views the whole farm as a system (holistic) but also focuses on the interdependencies of all the components under the control of the farm household and on the interaction of these components with physical, biological and socio-economic factors that are beyond the household's control. FSR aims at enhancing the efficiency of the FS by improving the focus of agricultural research in order to generate and test technologies in the best possible ways (Petersen, 1997; IPGRI, 2000).

2.3 Classification of livestock production systems

2.3.1 General classification

A livestock production system is a component of a FS whereby a livestock component is dealt with in combination with crop production or as a sole enterprise (Otte and Chilonda, 2003). Globally, livestock production systems have been classified into grazing, mixed and industrial production systems (Seré and Steinfeld, 1996; Kruska *et al.*, 2003). These authors put forward four categories of livestock systems; namely landless systems; livestock only/rangeland-based (areas with

minimal cropping); mixed rain fed systems (mostly rain fed cropping combined with livestock) and mixed irrigated systems (significant proportion of cropping uses irrigation and is interspersed with livestock) (Table 1). The grazing systems are referred to as livestock systems in which more than 90% of DM fed to animals come from rangelands, pastures, annual forages and purchased feeds and less than 10% of the total value of production come from non-livestock farming activities. In these grazing systems annual stocking rates are less than ten (10) livestock units (LU) per hectare of agricultural land (Seré and Steinfeld, 1996).

The industrial or landless livestock production systems described by Kruska *et al.* (2003) are also a derivative of Seré and Steinfeld (1996). These systems have stocking rates greater than ten livestock units per hectare of agricultural land (> 10 LU/ha). In the industrial livestock systems, less than 10% of the DM fed to livestock is produced on the farm (Seré and Steinfeld, 1996). The industrial system provides more than 50% of global pork and poultry meat production and 10% of beef and mutton production. However, their efficiency and functioning depend on outside supplies of feeds, energy and other inputs and demands for these inputs can thus have effects on the environment in regions other than those where production occurs. Similarly, the impact of livestock on the environment in these systems depends both on species [(Poultry production (broilers and layers), pig production, ruminant feedlot meat production, large-scale urban dairy production] and on the processing of the inputs (feed supply) and the outputs (animal products).

Table 1. Livestock production systems of the world

Production system	Examples
1. Temperate and tropical grassland (COLD GRASS)	<ul style="list-style-type: none"> • Mongolia's steppe • Dairy systems near Bogota, Colombia; Peru and Bolivia
2. Humid / sub humid tropics and subtropics (WET GRASS)	<ul style="list-style-type: none"> • Extensive ranching South American lowlands • Ranching systems in West / Central Africa
3. Arid / semi arid tropics and subtropics (DRY GRASS)	<ul style="list-style-type: none"> • Pastoralists in the Sahel, Near East and N. Africa • Beef-milk systems in Mexico, Venezuela, Southern Africa ranches
4. Temperate and tropical highlands mixed rain fed (COLD MIXED)	<ul style="list-style-type: none"> • Smallholder peasants in northern China • Smallholders in Ethiopian highlands where oxen for traction is important • Peri-urban dairy in East African highlands
5. Humid / sub humid tropics and subtropics mixed rain fed (WET MIXED)	<ul style="list-style-type: none"> • Areas of South America where rainforests are being cleared • Areas of sub-Saharan Africa ('tsetse belt')
6. Arid / semi-arid tropics and subtropics (DRY MIXED)	<ul style="list-style-type: none"> • Dry land farming-sheep systems in west Asia, North Africa and India • Small ruminant-cassava systems in Brazil • Mixed crop-livestock farms in Burkina Faso
7. Temperate and tropical highlands mixed irrigated (COLD IRRIGATED)	<ul style="list-style-type: none"> • Mediterranean region • Far East Asian irrigated rice / dairy farms
8. Humid / sub humid tropics and subtropics mixed irrigated (WET IRRIGATED)	<ul style="list-style-type: none"> • Irrigated rice-buffalo systems of the Philippines, Vietnam and India • Irrigated rice, pig/poultry enterprises in Asia
9. Arid / semi arid tropics and subtropics mixed irrigated (DRY IRRIGATED)	<ul style="list-style-type: none"> • Small scale buffalo milk production, Pakistan and India • Intensive dairy systems in California, Israel and Mexico
10. LANDLESS MONO-GASTRIC SYSTEMS: value for production of the pig/poultry enterprise > the ruminant enterprise	<ul style="list-style-type: none"> • Pig production in Asia, Poultry production in Central and south America
11. LANDLESS RUMINANT SYSTEMS: value of production of the ruminant enterprise > the pig / poultry enterprises	<ul style="list-style-type: none"> • Landless sheep production systems in west Asia-North Africa • Sheep fattening in Syria and Nigeria

Source: Kruska *et al.* (2003)

Seré and Steinfeld (1996) also defined mixed systems as those in which more than 10% of the DM fed to livestock comes from crop by-products and/or stubble or more than 10% of the value of production come from non-livestock farming activities. The authors argue that on a global scale, mixed farming systems produce the largest share of total meat (54%) and milk (90%) and that mixed farming is the main system for smallholder farmers in many developing countries. The source of animal feeds be it communal (natural) grazing, crop residues (harvest or fallow grazing), cut and carry processes and on farm or external supply of feed have a great impact on the environment and function of the system. Livestock production systems are, therefore, a subset of farming systems (FAO, 2004a). Practically, smallholder systems based on crop and livestock production have been developed in high potential areas of Tanzania and East Africa at large with varying degrees of success (Ogle, 1990; Bebe *et al.*, 2003a). The emphasis on small-scale dairying has been under zero grazing practices whereby the exotic and high milk producing cows (e.g. Friesian and Jersey) or the crosses of these breeds with other tropical breeds (e.g. Boran and Small East African Zebu) are used.

2.3.2 Characteristics of farming and farming systems of Tanzania

2.3.2.1 Overview

Tanzania has a total land area of 886,037sq km of which 4% is arable land and 38% and 40% respectively is permanent pastures and woodland (Tanzania, 2001). The country relies heavily on the agricultural sector that provides over 60% of her gross

domestic products (GDP) and over 50% of export earnings (THCL, 2001). Like many other countries in Africa, Tanzania's agricultural sector is dominated by smallholder farmers who own an average of 1.2 hectares of land and less than 5 heads of cattle per household (Newafrica, 1999). However, the farmers have access to communal grazing areas and roadsides where they obtain forages for cattle and other types of livestock. The smallholder farmers comprise of over 85% of the 34.6 million Tanzania's population (TNW, 2003).

2.3.2.2 Farming systems of Tanzania

Tanzania has diverse agro-ecological zones with varying altitudes, rainfall and soil types. According to the map of major crop zones of Tanzania shown in Figure 1 (FAO/GIEWS (2001) cassava and rice zones dominate the eastern, southern and northwestern parts of the country. At the same time, the western and south western (southern highlands) areas are recognised as maize zones. Similarly, the central regions were mapped by FAO/GIEWS (2001) as the sorghum-millet zone while the wheat zone was depicted in the northeast. This cropping information and that on livestock production is used to characterize the different farming systems of Tanzania (Ruthenberg, 1976; Schechambo *et al.*, 1999). According to Ruthenberg (1976), Tanzania's farming systems classifications include the fallow systems in Sukumaland (Shinyanga region) and those of arable irrigation in Tabora region. The former is characterised by annual crops like maize, legumes, sorghum and millets with livestock while the latter is based on wetland paddies. Furthermore, there are

systems of perennial cropping in the Lake Victoria Basin and Northern Tanzania where banana-coffee systems dominate (Maruo, 2002).

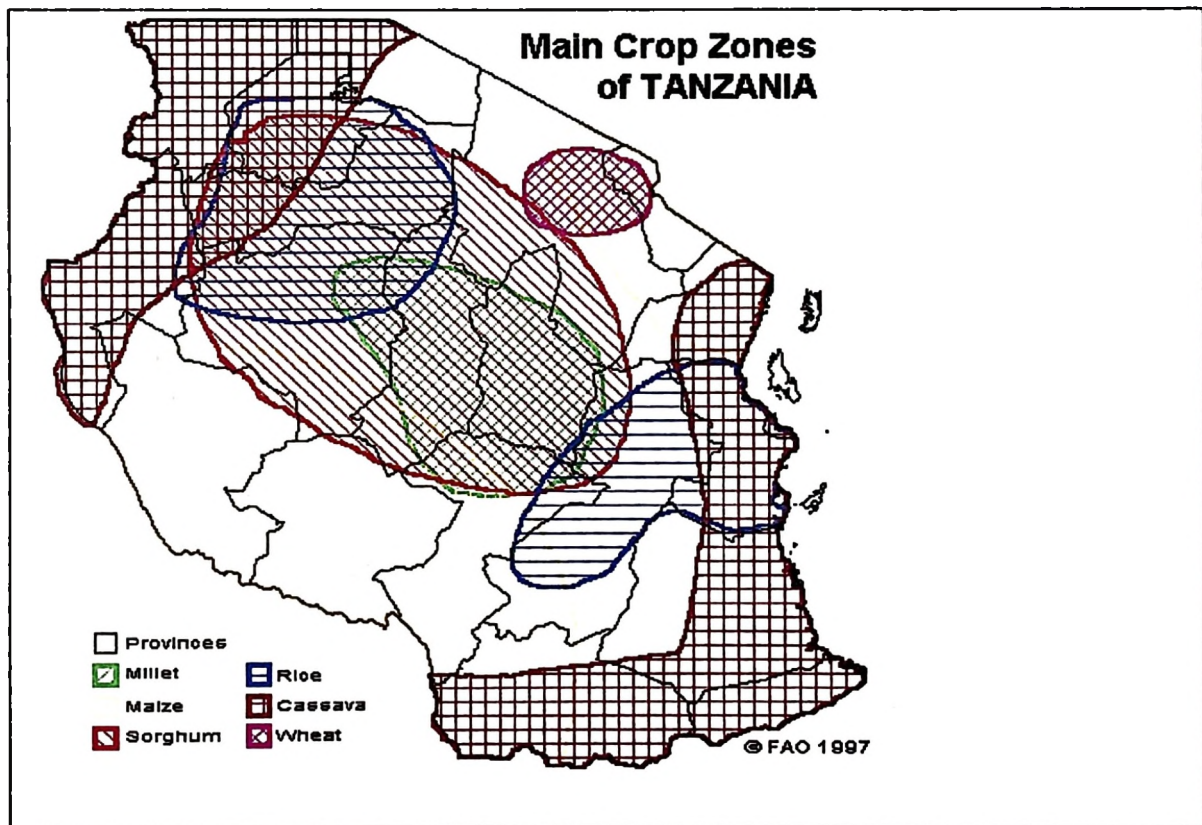


Figure 1. Main Crop zones of Tanzania
Source: FAO/GIEWS (2001)

Also included by Ruthenberg (1976) and Schechambo *et al.* (1999) were systems with plantation field and perennial tree crops in areas around the coastal belt in the Coast, Morogoro and Tanga regions. Table 2 presents a summary of major farming systems of Tanzania and their inherent characteristics.

Table 2. Major farming systems of Tanzania.

Serial number	Farming System type	Characteristics
1	Fallow	Characterised by annual crops like maize, legumes sorghum and millets with livestock
2		Cassava-cashew-coconut
3	Pastoralism	Livestock being the principal means of livelihood
4	Agropastoralism	Intimate cropping and livestock keeping. At least 50% of household needs come from livestock
5	Perennial cropping	Coffee, banana, horticultural cropping
6	Wet rice	Wetland paddy / sugarcane system
7	Irrigated agriculture	Wetland paddy / sugarcane system

Source: Modified after Schechambo *et al.* (1999)

2.3.2.3 The livestock sub-sector

In Tanzania the livestock sub-sector contributes 18% of the national GDP and 30% of the agricultural GDP (THCL, 2001). The sub-sector is largely run under smallholder, pastoral and agro pastoral production systems. The pastoral and agro pastoral production systems are concentrated in areas characterized by arid and semi arid climate. In these areas rains are unreliable with annual rainfall of between 200 and 800 mm (Schechambo *et al.*, 1999). Food crops widely grown include short-term maturing varieties of maize, groundnuts, sorghum and millets that provide the bulk

of crop residues mainly for cattle, sheep, goats and donkeys. Sarwatt and Mollel (2000) indicated that the semi arid regions of Tanzania comprise of about 30% of the total land area and inhabit over 80% of all of Tanzania's major ruminant livestock (cattle, sheep and goats). The grazing and mixed livestock production systems are, therefore, predominant with ruminants and monogastrics (poultry and pigs) being unevenly distributed among the different agricultural systems (MAFS, 2001).

2.4 Utilization of LK in the management of natural resources

Different pastoral and agropastoral communities use LK to describe climate, soils, plants and vegetation (Niamir, 1990; Lugeye, 1994; Kamara, 1995). Niamir (1990) reported that the emergence of frogs, birds, insects and position of some stars are descriptive signs for the onset of rains for both the Turkana of Kenya and the Fulani of Mauritania. Rutatora (1995) gave an example of the Wandali of Mbozi district in Tanzania who use certain types of plants to indicate fertility or agricultural potential of the land and hence determine the type of crops that can be grown in specific localities. Equally, Niamir (1990) reported that the Bambara of Mali classify soils based on ease of cultivation and on their potential for certain crops.

It is only recently that LK has been acknowledged to have substantial impacts in socio-economic and other development matters (Chambers, 1986; Nielsen, 1998). Nevertheless, LK has always been utilised in agricultural research and development (R&D) in developing countries for some time. Larsen (2000) reported that LK is used in classifying landscape for grazing, seasonal movement of animals, for resting

of pastures and watering points and for efficient utilization of various grass and browse species in rangeland ecosystems (Figure 2). It is generally envisaged that the descriptive nature of LK in the aspects of land use including the utilization of grass and browse species underlie the beneficial and sustainable use of the vast resources (Chambers *et al.*, 1989).

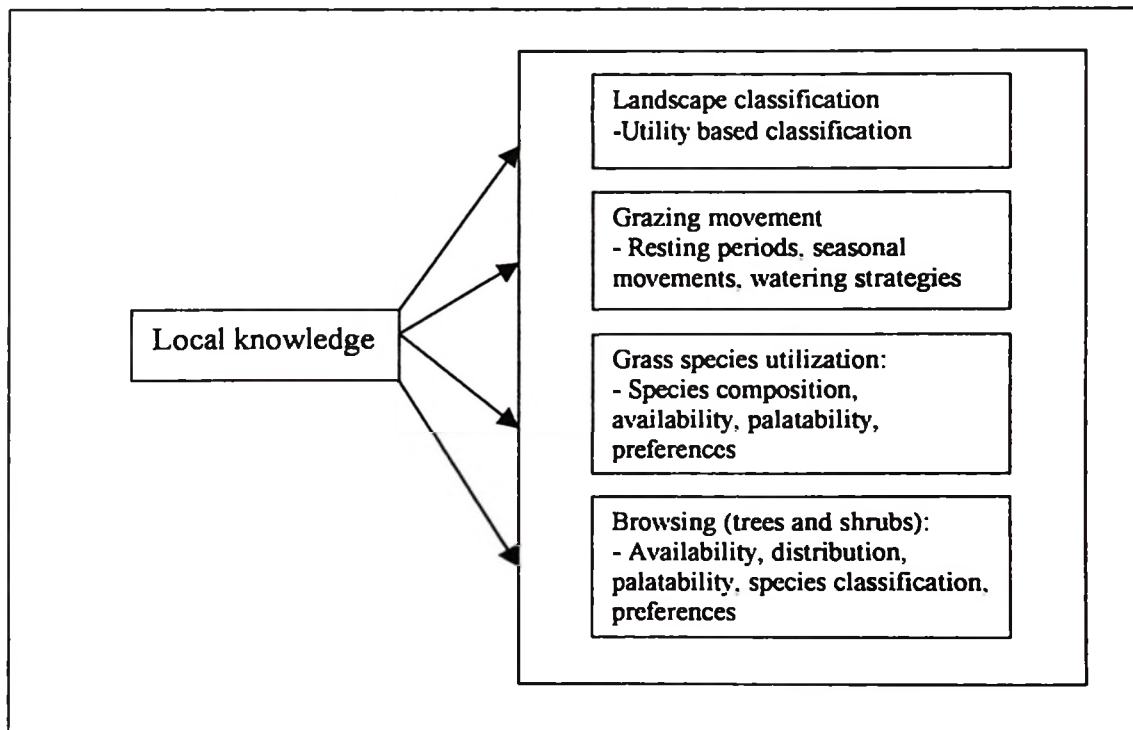


Figure 2. Identifying interactions between livestock production and natural resource utilization through local knowledge.

Source: Larsen (2000)

2.4.1 Local knowledge in crop and livestock production

Local knowledge on different types of fodder and their feeding values was evident among different societies as described by Lamprey *et al.* (1980), Fenna *et al.* (1998), Thorne *et al.* (1999), Walker *et al.* (1999) and Komwihangilo *et al.* (2001). The different types of grasses, forbs, and legume trees and shrubs are recognised by farmers and used for cattle, sheep, goats and other classes of livestock. Strategic uses of these feeds are reported to lead to improved milk yield and higher butter fat (Walker *et al.*, 1999) or promoted growth rates (Komwihangilo *et al.*, 2001).

In animal health-care, Bitegeko *et al.* (1995) reported that some smallholder farmers in Tanzania use *Psidium guajava* leaf extracts in treating diarrhoea and dysentery. The authors also cited, among other species, the use of *Syzygium cuminii* leaf, bark and root extracts for sedation and tranquillisation in cattle. ole Lengisugi (1995) reported experiences of the Maasai who provide soil licks to livestock as mineral supplement so as to confer resistance to illness, to enhance appetite, growth and *libido* and to promote milk production. Moreover, Nuwanyakpa *et al.* (2000) reported a combination of indigenous plants such as *Indigofera spicata* and supernatural beliefs in various ethnoveterinary practices of the Fulani pastoralists. Most recently, Douthwaite *et al.* (2003) informed on how farmers in Eastern Uganda recognised the role of *Mucuna* and other legumes not only as suitable cover crops for fertility management but also for other benefits such as fuel wood, fodder and medicinal purposes.

2.4.2 Local knowledge and farmer experimentation

Kajembe *et al.* (2000a) reported that farmers' experiments could be categorised into three kinds: *curiosity*, *problem solving* and *adaptation*. The authors gave an example of a Peruvian farmer whose curiosity led to conducting an experiment to ascertain whether epical dominance would affect the number and size of potato tubers. The authors reported also on how farmers developed techniques to eradicate termites that were destroying young seedlings. The authors observed further that adaptation experimentations were common among farmers whereby an unknown technology would be tested in a known environment or a known technology would be tested in a new environment. Quoroz (1996) reported that farmers' experimentation enables them to cope with variability, uncertainty and complexity of their living and production environments. In this way, farmers could maintain the crop varieties, animal species, soil productivity and other resources. Quoroz (1996) argued further that knowledge generation through farmer experimentation draw on both local methods and 'formal scientific' methods of experimentation.

On the other hand, Sinclair and Walker (1999) argued that there are marked differences between what people do and what they actually know. This had been reflected by the fact that agricultural practices in many rural communities are a result of interactions between underlying knowledge and a series of events, opportunities and constraints rather than carefully planned events. Moreover, Sinclair and Joshi (2001) were of a view that knowledge is not directly inferred only from observation of practice. To support this, the authors gave a case from the hill farming systems in

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Nepal where farmers' knowledge of the propensity of broad leaved trees (e.g. *Ficus roxburghii*) in causing splash erosion of soil did not deter them in planting these trees as sources of animal fodder because these trees were hailed for their high feeding value.

2.4.3 Limitations in accessing and utilizing local knowledge

Limitations to accessing and utilizing LK have been identified to originate largely from the nature or type of knowledge and methods of storage and transmission (Kauzeni and Madulu, 2001). Traditionally, accessibility to LK that is categorised as 'general' or 'public' knowledge (such as that on weather or crop varieties) was and is still easier than accessibility and sharing of the 'more sensitive' knowledge (such as that of medical nature), which was and is usually treated as 'secret' and 'more personal'. Studies from Cameroon showed that the secrecy of medical knowledge was felt ideal for sustaining the 'healing power' of bearers and the plant materials they used (Nuwanyakpa *et al.*, 2000). Moreover, it is widely recognized that LK is stored within people's minds (mostly elders) and is traditionally passed on to the young (or to any body in need) by word of mouth. Thus, it is prone to being lost as the custodian becomes less capable through ageing or when 'the expert' perishes through death (Kauzeni and Madulu, 2001). Similarly, technological and cultural modernisation and other socio-economic developments are putting enormous pressures to accessibility and utilization of LK (Agrawal, 1995; Mogoia and Nyangito, 1999; Kauzeni and Madulu, 2001).

On the other hand, many scholars of 'formal (natural and applied) sciences' have the 'narrow' but 'more general view' that LK or IK encompass the 'backward and uncivilized way of living' (Köhler-Rollefson, 1996). However, these views have been attributed by the fact that by its very nature, LKS represents a more descriptive social and ecological reality than the more quantitative data used in formal scientific sampling methods (Chambers *et al.*, 1989).

2.4.4 Amalgamating local knowledge with formal scientific knowledge

In recent times, many workers have acknowledged complementarities and synergy of the two knowledge systems, that is, the local and formal scientific knowledge. For example, Nuwanyakpa *et al.* (2000) observed that among the Fulani pastoralists there is a blend of natural plants and belief in supernatural healing (through Arabic prayers taken from the Koran). However, plants such as *Indigofera* spp that are used have been proved to have anti-bacterial and anti-inflammatory properties for the control of mastitis. Subedi (2001) reported relationships of farmers' views on goodness of green leaf when used as manure and chemical composition (nitrogen, phosphorus and potassium) of the plants tissues formally determined in the laboratory. On the other hand, formal scientific literature has revealed that although local people had many years of experience in traditional processing of the alcoholic beverage (*mbege*) with yeasts (*Saccharomyces cerevisiae*) and bacteria (*Lactobaccillus plantarum*) from the local resources, the beer would be more hygienic if the spoiling micro organisms (*Acetobacter*) were minimised (Shayo *et al.*, 1998). That is why Thapa *et al.* (1995) and Haverkort (1996) argued that during investigation of LK, researchers

could learn good things about the system and / or expose inaccurate and technically outdated components so that in this process they can allow identification of complementary scientific knowledge. Similarly, Walker *et al.* (1999) noted that amalgamating LK and formal scientific knowledge may be a more powerful tool in designing appropriate agricultural practices than the use of either alone. The integration is expected to lead to efficient use of resources through appropriate targets of research and extension (Munyanziza and Wiersum, 1999). Nevertheless, this requires integration or the use of informal and formal approaches in soliciting information from farmers (Norman *et al.*, 1994) as well as applying other conventional scientific approaches (Thapa *et al.*, 1995).

2.5 Farmers' choice of technologies and criteria for resource assessment

2.5.1 General views for farmers' choice of technologies

Some farming systems research activities (Jabbar and Diedhiou, 2001; Ayalew *et al.*, 2003) have indicated that farmers have various reasons to accept or reject technologies. Their choice is, however, based on complex sets of criteria (Walker *et al.*, 1999). For example, the suitability of various species as cover crops in fertility management or yields of seeds, fuel wood and fodder were some of the criteria identified in a study on evaluating legumes in Tororo district, Uganda (Table 3). The choice of the type of animals suitable to local conditions was also based on local criteria as reported by Jabbar and Diedhiou (2001) and Bebe *et al.* (2003a) who established that milk yield, disease resistance, body size, marketability, grazing

diversity and mobility were important criteria in the selection of indigenous and exogenous cattle breeds.

Table 3. Criteria used by farmers to rank shrubs and legume cover crops (LCC)

Criteria	How farmers assess criteria
Yield increase of crop after fallow intercrop	Weight of grain, bunch or fruit.
Crop vigour after fallow or intercrop	Health of plants Greenness of leaves
Soil fertility increase	Darkening of soil colour Depth of soil increased Ease of ploughing; soil erosion control Moisture retention Time taken to cause significant fertility increase
Ease of germination, establishment and seed production of the LCC or shrub	More seeds produced in a short time and viable for longer time
Multiple uses of LCC or shrub	Small seeds difficult to collect The number of other additional uses from the LCC or shrub e.g. firewood, medicine or fodder.
Sustainability for intercropping	Intercrop compatibility i.e. minimal competition of LCC or shrub with the crop
Ability to control weeds	Dense canopy formation which suppress undergrowth
Amount of biomass production	Number of leaves, size of leaves Ground coverage, shorter maturity period
Labour requirement for clearing, uprooting, cutting and incorporation	Ease of bush clearing, uprooting, cutting stems and leaves and then incorporation into the soil

Source: Douthwaite *et al.* (2003)

In Nigeria, for example, Jabbar and Diedhiou (2001) recorded that among the five breeds evaluated N'Dama was the most preferred in terms of disease (Trypanosomiasis) resistance while White-Fulani was the most preferred for milk yield. In Kenya, however, Bebe *et al.* (2003a) noted that larger *Bos taurus* breeds

(Friesian, Ayrshire) were more preferred for milk yield while the *Bos indicus* breeds (East African Zebu, Boran and Sahiwal) were preferred for traction and tolerance to harsh conditions.

2.5.2 Farmers' criteria in the description of forage quality

In the work conducted in the Uluguru Mountains in Tanzania, Jänhing (1996) reported on criteria used by goat keepers in the selection of fodder. These were based on reasons of livestock keeping or objectives of production (e.g. to obtain manure or get more milk). Thus stomach fill, animal forage preferences, medicinal effect of forages and seasonality of forage supply were identified as some of the criteria used in qualifying forages.

Thorne *et al.* (1999) and Walker *et al.* (1999) noted that farmers in Nepal describe *pasilo* fodders as those capable of promoting milk yield and butter fat as well as rapid weight gain of livestock. On the other hand, the authors reported that those fodders characterised as *kam pasilo* may, if fed alone, cause weight loss, reduction in milk yield and deterioration in health. Furthermore, livestock keepers keep stock of factors that affect quality of fodder and they strive to maintain quality. Thapa *et al.* (1995) stressed that farmers in the hill-farming systems of Nepal considered that the season, extent and technique of lopping trees affect the amount and quality of fodder produced from different trees.

2.6 Farming systems research methods used in LK studies

Norman *et al.* (1994) identified the structured and unstructured surveys (formal and informal), observation and direct measurement to be the most common methods used in gathering data in FSR. These methods were also reported by Maundu (1995) and King (2000) to be appropriate in LK studies. The choice of a method depends on many factors including the study discipline (e.g. socio-economics, anthropology, forestry, animal science e.t.c.), the objective of the research, the quality and quantity of resources available, time allocated for the study and complexity of the farming system under study (King, 2000). However, Kajembe (1994) proposed that LK studies could employ a combination of different methods for more meaningful and accurate data. The next sections give a review of secondary sources, participant observation, participatory rural appraisal (PRA) and formal surveys with pre-prepared questions.

2.6.1 Review of secondary sources

Review of both published information and grey literature is an important tool for gathering data on any subject including LK. Beside providing first hand information, a wider literature review is important because it could help in clarifying doubts or in verifying findings recorded in the course of a study. For example, published observations and experiences in ethnoveterinary (Bitegeko *et al.*, 1995; ole Lengisugi, 1995; Nuwanyakpa *et al.*, 2000), natural resources (Munyanziza and Wiersum, 1999; Kajembe *et al.*, 2000a,b; Larsen, 2000) and general agricultural

practices (Niamir, 1990; McCall, 1996) provide salient features of farmers' understanding of crop and livestock production systems and resources in Sub-Saharan Africa. On the other hand, a range of data base systems that vary from Geographical Information System (GIS) applications in recording the agronomic practices to ethno-botanical knowledge associated with families of useful plants are increasing steadily (Myer, 2000). This is because of concerted efforts by individual researchers as well as by regional and international institutions (Myer, 2000; CIRAN, 2001). Local communities, researchers, policy makers and programmers who are interested in LK aspects may access these sources of information.

2.6.2 Participant observation

Participant observation is defined as a systematic continuous way of obtaining and documenting information without disrupting the processes, people or locations being observed (King, 2000). Observation is pervasive to daily life situations and as a scientific technique it is applied both in social sciences or laboratory activities (Ott and Longnecker, 2001). Seltiz *et al.* (1959) reported that where applied by anthropologists, this technique could lead to uncovering facts that informers would never have thought of reporting. Maundu (1995) commended the methodology when he argued that the researcher could identify sites, vegetation and other interesting features without enquiring from anybody. In the course of observation, however, the researcher might ask some clarification questions from even a small child who would otherwise be overlooked. Moreover, King (2000) stressed that the application of observation as a methodology in LK studies can lead to not only more general

understanding of sites, resource diversity and farmers' activities but also may contribute in supporting other information obtained through other methods.

2.6.3 Participatory Rural Appraisal (PRA)

Participatory Rural Appraisal (PRA) is a research approach developed in the late 1970s and early 1980s (Norman *et al.*, 1994; IPGRI, 2000). It is an intensive, systematic, but semi-structured learning experience carried out in a community by a multi-disciplinary team, which includes community members. With the PRA it is possible to investigate, analyse and evaluate constraints and opportunities in general. PRA sessions can also be organised for specific topics (topical PRA) such as that on LK on forage quality. PRA makes use of a wide range of techniques / tools including review of secondary data, direct observation, focus group discussions, pairwise ranking, direct matrix ranking, ranking by voting, wealth ranking, transect (walks), time trends, venn / institutional diagrams and many others (Norman *et al.* 1994; Lyimo, 1998, King, 2000). However, not all PRA tools are used in every PRA session. Some PRA tools are suitable for data collection (direct observation, review of secondary sources, semi-structured interviewing) while others are better for data analysis (innovation assessment). Some tools such as ranking techniques and some diagrams can be used for both information gathering and analysis (Lyimo, 1998).

2.6.4 Formal surveys with structured questionnaires

Formal surveys involve the use of structured questionnaires (that is, a list of questions prepared before hand) that provide a systematic way of obtaining information from respondents. The information obtained can be statistically analysed. A number of visits and frequency depends on quality of information needed and costs involved (Norman *et al.*, 1994). A formal survey can either be cross-sectional or longitudinal in nature. The former approach enables the researcher to have a description of phenomena in the location at a single point in time (Gujarati, 1995). Cross-sectional surveys may give valuable description and relationships of parameters in the area under study prior to undergoing the longitudinal approach where the same respondent(s) are interviewed in subsequent times e.g. seasons or specific time period e.g. monthly.

2.7 Criteria and techniques used by formal scientists in qualifying forages

Information obtained through laboratory analysis of feed composition, estimates of digestibility and degradability of nutrients as well as the results on production responses are often used by researchers as criteria in qualifying forages and other animal feeds (Crowder and Chheda, 1982; McDonald *et al.* 1998; Relling *et al.*, 2001). This information is generated through different techniques such as those involving animals in measurements of the quantity of feed intake or physiological and behavioural responses.

2.7.1 Chemical composition

Laboratory analyses of chemical composition such as nitrogen, ash or detergent fibre determinations and amount of specific anti-nutritional components are often basic considerations in quality assessment. Minson (1990) cautioned that care should be taken in comparing composition of grass and other pasture species since composition vary with species and varieties, climate and soil fertility. Moreover, the stages of growth greatly contribute to further variations (Section 2.8.1). Table 4 shows ranges of crude protein (CP) composition, acid detergent fibre (ADF), cellulose, moisture, ether extracts (EE) and minerals of grass forages (McDonald *et al.*, 1998).

Table 4. General chemical composition of grass forages

Proximate composition	Range (g/kg DM)
CP	30 – 300
Fibre - NDF	Inversely related to CP
- ADF	200 – 450
Moisture	Young 750 – 850 Mature \approx 650
Cellulose	200 – 300
Hemicellulose	100 – 300
Lipid (EE)	\leq 60
Minerals	Variable, depending on species, stage of growth, soil type, cultivation conditions and fertilizer application

Source: Modified after McDonald *et al.* (1998)

Generally, legumes are better in CP content than grasses. Dermaquilly (1989) observed that the protein value of grass expressed in CP varied from 5 to 15% and 10 to 20% for tropical and temperate species respectively and between 15 and 25% for legumes. However, the author stressed that apart from composition (e.g. CP) it was also important to know the proportion of protein degraded in the rumen, the

proportion that escapes rumen degradation and that which is digested in the intestines.

Table 5(a), 5(b) and 5(c) show composition and nutritive value of some of the tropical grasses, legumes and forbs and crop by-products respectively reported by different authors. There are variations in composition and nutritive values within and between the forages and other feeds. However, stages of growth of the forages, climatic and soil conditions where the plants were grown as well as forage genotypes may have contributed to the variations observed (section 2.8). At the same time, differences due to analytical procedures emanating from and intra or inter-laboratory variations need not to be overemphasised in this aspect (Verese gyházy *et al.*, 1989; Huntington and Givens, 1995).

2.7.2 *In vitro* digestibility

The digestibility of the feed, that is the proportion of feed which is not excreted in the faeces and which is, therefore, assumed to be absorbed by the animal (McDonald *et al.*, 1998), is an important consideration in the description of quality of feeds. This is often measured directly using animals (*in vivo*) section 2.7.4) or indirectly with laboratory based (*in vitro*) methods. In the former approach, experimental animals are given known amounts of food in a specific period and output in faeces is measured. However, the *in vitro* methods involve the use of rumen liquor or enzymes incubated in the test feed following the Tilley and Terry (1963) method also known as the two-stage method.

Table 5 (a). Composition (g/KgDM) and nutritive value of selected tropical grasses by different workers

Name of feed	DM	Ash	CP	NDF	ADF	CF	NFE	EE	Ca	P	IDMD	IOMD	Energy	Reference
<i>Panicum maximum</i>	240	125	72	728	482	-	-	-	3.0	2.0	442	438	2.77	Temi (1999)
	-	98	40	755	460	-	-	-	-	-	-	579	9.26	Bwire <i>et al.</i> (2003)
	939	-	71	678	400	-	-	-	3.27	2.38	-	-	-	Shem <i>et al.</i> (1999)
<i>Pennisetum purpureum</i>	194	120	43	752	-	356	-	-	3.3	1.3	-	-	-	Pendo <i>et al.</i> (1999)
	204	128	93	631	-	-	-	-	-	-	654	619	8.89	Msangi and Kizima (1999)
	250	126	67	711	455	-	-	-	-	-	-	-	6.0	Machibula (2000)
	293	-	161	-	-	335	-	28	4.4	1.6	522.0	-	6.90	Temu <i>et al.</i> (1998)
	145	-	110	-	-	-	-	-	-	-	-	-	9.60	Shem (1993)
<i>Panicum trichocladum</i>	416	98	78	-	-	-	-	-	4.3	1.7	526.0	-	7.12	Fenna <i>et al.</i> (1998)
	257	-	109	-	-	373	-	-	2.7	0.9	542.0	-	7.29	Temu <i>et al.</i> (1998)
	176	116	86.6	-	-	-	-	-	-	-	-	730	11.68	Mussa (1998)
<i>Rottboelia cochinchinensis</i>	354	-	126	-	-	312	-	19.6	3.8	1.3	572.2	-	7.69	Temu <i>et al.</i> (1998)
	252	132	73	740	397	-	-	-	2	2	547	561	8.78	Temi (1999)

Table 5 (b). Composition (g/KgDM) and nutritive value of selected tropical legumes and forbs by different workers

Name of feed	DM	Ash	CP	NDF	ADF	CF	NFE	EE	Ca	P	IDMD	IOMD	Energy	Reference
<i>Vigna pubescens</i>	261	91	142	553	457	-	-	-	1.3	0.2	494	492	6.54	Temu (1999)
<i>Macroptilium atropurpureum</i>	300	-	177	-	-	356	-	260	-	-	561.3	-	7.53	Temu <i>et al.</i> (1998)
<i>Gliricidia sepium</i>	921	99	212	454	298	-	-	-	-	-	-	-	9.50	Machibula (2000)
	359	-	182	-	-	164	-	31.1	1.4	0.3	424.9	-	2.52	Temu <i>et al.</i> (1998)
<i>Ipomoea aquatica</i>	243	102	235	498	301	-	-	-	1.4	0.2	573	576	7.70	Temu (1999)
	166	-	167	-	-	201	-	20.6	4.5	1.6	559.4	-	7.50	Temu <i>et al.</i> (1998)
<i>Commelina spp</i>	83	141	267	-	-	155	-	67	9.0	2.0	-	-	10.6	Men (1999)
	394	-	669	-	-	-	-	-	3.9	1.3	623	-	8.70	Mtengeti <i>et al.</i> (1998)
	145	-	204	-	-	373	-	20.6	2.4	0.8	721	-	9.87	Temu <i>et al.</i> (1998)
	135	142	120	-	-	-	-	-	6.5	2.5	635	-	7.85	Fenna <i>et al.</i> (1998)

Table 5 (c). Composition (g/KgDM) and nutritive value of some supplementary by-products by different workers

Name of feed	DM	Ash	CP	NDF	ADF	CF	NFE	EE	Ca	P	IDMD	IODM	Energy (MJ ME/kgDM)	Reference
Hominy meal (Maize bran)	904	46	116	340	118	88	664.0	85	-	-	-	-	13.80	Bwire and Wiktorsson (1996)
	942	26	85	500	125	-	-	-	-	-	-	-	11.00	Machibula (2000)
	856	64	121	-	-	47.7	-	7.1	3.2	8.3	-	-	-	Maeda (2000)
	932.2	52.3	120.2	31.0	392.1	50.1	672.4	33.5	8.7	2.9	-	-	12.19	Kimbi (1997)
	917	25	92	-	-	107	726.0	50.0	9.6	7.8	72.8	72.0	13.35	Ndemanisho (1996)
Sunflower seed cake	932	51	219	519	459	345	214	170	-	-	-	-	12.6	Bwire and Wiktorsson (1996)
	909	50.3	259	-	-	90.9	332.6	187.1	3.0	9.1	-	-	10.12	Maeda (2000)
	968	46.0	297	-	-	276	302.0	44.0	-	6.0	-	-	20.50	Mellau (1999)
Cotton seed cake	924	90	291	419	391	291	135	187	-	-	-	-	12.70	Bwire and Wiktorsson (1996)
	869	61.6	352.6	324.1	252.5	231.6	131.9	90.9	-	-	-	-	10.05	Murro (2002)
	930.5	57.5	252.6	467.7	377.7	302.9	278.8	70.5	4.2	6.4	-	-	10.65	Kimbi (1997)
	931	62.0	332	-	-	167.0	327.0	110	2.7	8.1	53.2	50.2	12.62	Ndemanisho (1996)

The first stage involves the incubation of a small sample of dried forages in the rumen fluid and allows anaerobic digestion at 38°C with buffer added to maintain neutral levels of pH. The sediment obtained after centrifuging by the end of the 48-hour period is used in the second phase. The second stage involves the addition of pepsin to allow digestion of undegraded portions of the feeds that include rumen by pass protein and microorganisms in the substrate. Despite attempts in modifying the procedure such as those of Verese gyházy *et al.* (1989) the basic Tilley and Terry (1963) procedure is still useful to allow numerous samples to be analysed in a relatively short time.

2.7.3 Degradability with *in sacco* technique

The proportion of DM and protein in ingested feed that escapes rumen degradation, which can be absorbed through the lower gut of ruminants, is referred to as *degradability*, and this is also vital in the description of feed quality. To estimate this proportion the *in sacco* (or *in situ*) method is widely used (Michalet-Doreau and Ould-Bah, 1992; Huntington and Givens, 1995). The method requires suspension of nylon bags containing feeds in the rumen of fistulated animals (mainly cattle and sheep) at varying time intervals. The Agricultural and Food Research Council (AFRC, 1992) recommended 0, 8, 12, 24, 48 and 72 hours for forages and 0, 2, 4, 8, 16, 24 and 48 hours for concentrates. Similar incubation time periods were proposed by Madsen and Hvelplund (1994) though Osuji *et al.* (1993) recommended that incubation time would be extended up to 120 hours for tropical forages.

The *in sacco* technique provides estimates of rate and potential degradability of DM or CP in feeds through the famous Ørskov and McDonald (1979) model. The degradability model (i):

$$dg = a + b (1 - e^{-ct}) \dots\dots\dots \text{model (i)}$$

where:

dg = degradability at time t (hours)

a = the readily soluble material at 0 time measurement of degradability

b = insoluble but potentially degradable material

c = rate constant at which b is degraded

e = natural logarithm to base 10

The model (i) can be used with or without lag phase, that is, time when there is assumed to be no or insignificant action of rumen microbes in the degradation of feed (Kraus *et al.*, 1997) (model (ii):

$$dg = a + b \{1 - e^{-c(t-t_0)}\} \dots\dots\dots \text{model (ii)}$$

for $t > t_0$ where:

a, b, c and t as defined by model (i)

t_0 = the lag time

The degradability models described above (model (i) and (ii)) provide the curve constants, a, b and c that can be used together with predicted outflow rate for a specified diet to estimate the effective degradability (p) as shown by Huntington and Givens (1995) (model iii):

$$p = a + ((b*c)/(c + k)) \dots\dots\dots \text{(model iii)}$$

where a, b and c are as described in equation (i)

k = is the rate of passage from the rumen, per hour

2.7.4 Feed intake and *in vivo* digestibility

Despite the widespread use of *in vitro* methods (section 2.7.2), the quality of feed could be explained better when measurements involve the direct use of animals (*in vivo*). In *in vivo* digestibility trials, the food under investigation is given to the animal in known amounts and the output of faeces and/or urine measured (McDonald *et al.*, 1998). The direct use of animals also lead to estimation of voluntary feed intake (VFI), which is the weight of food eaten when animals have free access to food in a given period of time. Although VFI has also been considered as an index of forage value (Forbes, 1995), intake experiments and others that aim at measuring physiological effects (e.g. growth and milk yield) are also common in describing feed quality (Hvelplund, 1999). Section 2.9 reviews various factors affecting intake on range or under stall-feeding systems.

Dry matter intake (DMI) is the most important variable affecting animal performance and the quantity of herbage consumed whether on free range or under confinement. DMI is also a determinant of forage quality (section 2.9) and various ways have been proposed in expressing intake values. Voluntary intake can be expressed as kg of forage DM eaten per 100 kg live weight or g/kgLW (Crowder and Chheda, 1982). Minson (1990) noted that in order to correct for differences in intake that arise due to species or size of animals, most data are reported in terms of metabolic weight of the animal which is expressed as live weight (LW) raised to 0.75 power ($LW^{0.75}$). Intakes are therefore shown in g / kg $LW^{0.75}$.

2.7.5 Forage quality assessment based on feeding behaviour

It was pointed out by Boumont *et al.* (2003) that intake is influenced by hunger which is distressing and by satiety, which is pleasurable. Eating behaviour studies that describe feed choices, preference and palatability of forages utilize bite numbers, bite mass and bite rates in order to estimate forage intake (Crowder and Chheda, 1982; De Rosa *et al.*, 1997; Fraser and Baker, 1998; Boumont *et al.*, 2003). However, it has also been reported (Boumont *et al.*, 2003) that feed intake and dietary choices combine short-term control of feeding behaviour related to body homeostatic regulation, and long term control that depend on nutritional requirement and body reserves. The short-term regulation of intake refers to within-day events (Mertens, 1987). Most of the feeding behaviour studies are short-term based and mostly utilize grazing livestock (Black and Kenney, 1984; Forbes, 1988; Lyons *et al.*, 1999; Boumont *et al.*, 2003) and information based on zero grazed cattle is therefore scanty. Nevertheless, available information shows that preference and palatability differ between and within plant species (Wandera, 1996; De Rosa *et al.*, 1997). In his comprehensive review of several studies, Wandera (1996) reported a study on palatability of different tropical forages which showed that the order of palatability of different grasses was: *Themeda triandra*, *Pennisetum clandestinum* (Kikuyu grass), *Hyperrhenia rufa*, *Pennisetum* spp., *Cynodon plectostachyum*, *Leptochloa obtusiflora*, *Chloris gayana* (Rhodes grass), *Paspalum dilatatum*, *Panicum trichocladum*, *Paspalum scrobiculetum*, *Brachiaria soluta* and *Eragrostis paniciformis*. On the other hand, De Rosa *et al.* (1997) evaluated dietary preferences of temperate grasses and legumes. Their results indicated that goats preferred grasses

to legumes and *Trifolium repens* (clover) to *Medicago polymorpha* (alfalfa). During foraging behavior studies, bites and other parameters can be recorded manually (Forbes, 1988) but with advancing technology automated recorders equipped with videos (Orr and Cook, 2003) could also be used.

Feeding behavioural studies have shown that initial rate of intake represents the motivation to eat and is a key factor for understanding palatability and voluntary feed intake of different forages (Boumont *et al.*, 2003). Earlier studies (Black and Kenney, 1984) also demonstrated that this intake rate was related to bite rate.

2.8 Factors affecting forage quality

2.8.1 Stage of growth

It is generally accepted that composition and nutritive value of pasture herbage is affected by stage of growth of species. This is illustrated in the growth curve of a plant (Figure 3). McDonald *et al.* (1998) reported that decreasing crude protein (CP) content with age has reciprocal relationship with fibre contents. Similarly, Amrane and Michalet-Doreau (1993) and Relling *et al.* (2001) showed that increase in DM as a result of advancing age is reflected in increase in ADF, ADL and NDF fractions due to increase in cell wall contents (cellulose and hemicellulose). This also leads to decrease in cell contents that result in lower CP, phosphorus (P) and potassium (K) percentages.

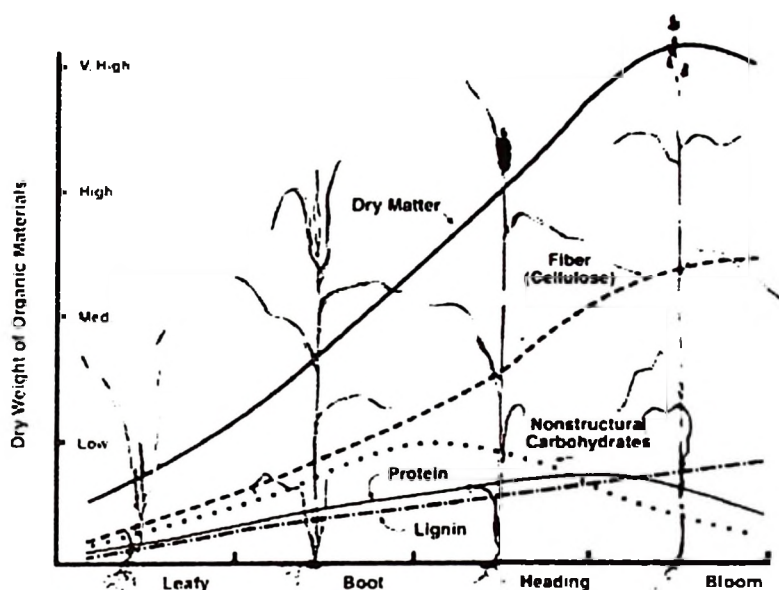


Figure 3. Variation of plant quality with stage of maturity

Source: <http://www.tamu-commerce.edu/coas/agscience/clasnote/advforagemana9/lecture1.ppt> (page visited 18/05/2004).

2.8.2 Soil types and fertilizers applied

Inherent mineral content in soils where pastures grow and those minerals applied as fertilizers were shown to have significant influence on mineral composition of the forages (McDonald *et al.*, 1998). Leng (1997) also reported that although deficiencies do limit growth of pasture species, similar trends might lead to reduced concentration of minerals in plant tissues. Excessive application of nitrogenous (N) fertilizers might lead to increased leaf area; alter botanical composition by increasing grass growth and reducing legume growth (Martha *et al.*, 2004). This practice is also reported to increase crude protein content and reduce water-soluble carbohydrates especially for temperate species (McDonald *et al.*, 1998). However, N fertilizers have shown inconsistent effects on DM digestibility especially to tropical grasses

(Minson, 1990; Martha *et al.*, 2004). It was reported by Moss (2003) that a well fertilised and actively growing tropical grass pasture could provide 9 MJ ME/kg DM and 14 to 19% CP. Such pastures contain 30 – 45% green leaf. In contrast, mature pasture or unfertilised grass with low leaf content may offer as low as 7 MJ ME/kg DM and 6-10% CP.

2.8.3 Climatic conditions

Seasonal variations, especially in tropical climate with distinct wet and dry seasons, have significant influence on chemical composition (Relling *et al.*, 2001). Crowder and Chheda (1982) reported that despite its influence on yields of green material and DM, the amount of precipitation directly influences crude protein, silica, free ash and NFE. Similarly, high heat intensities contribute to reduced digestibility and nutritive value because they cause rapid plant growth, enhanced maturity with decreasing leaf: stem ratio and increased CF (Minson, 1990).

2.8.4 Genotype

Despite differences in chemical composition between grass and leguminous species, there are also differences in composition and nutritive values when different genotypes within species are considered (Dermaquilly, 1989). Important genotypic factors that indirectly influence the chemical composition and nutritive values of herbage of different genotypes include differences in maturity dates, leaf: stem ratio,

growth habit and responsiveness to fertilizer and other management practices (Crowder and Chheda, 1982; Minson, 1990; Amrane and Michalet-Doreau, 1993).

2.9 Factors affecting voluntary feed intake

There are various interacting factors that may cause cessation of eating by the animals. These include feed quality, animal physiological state and metabolic requirements (Mertens, 1987; Ketelaars and Tolkamp, 1992). Such factors are reviewed below in three categories namely plant, animal and environmental factors.

2.9.1 Plant factors

2.9.1.1 Chemical structure of plants

The plant factors that are associated with intake of feeds include structural substances and the physical form of the materials given to the animals. The structural substances that are observed to limit intake are the total cell wall (NDF) contents (Van Soest, 1994). The cell wall contents are mainly cellulose, hemicellulose, lignin and residual ash. The nature of bonding of the lignin to the hemicellulose acts as a barrier to digestion (Kohn and Allen, 1992; McDonald *et al.*, 1998). On the other hand, feed substances with higher contents of phenolic compounds such as browses tend to lower intakes and digestibility of more feed because of the inhibitory effects of the phenolic acids (Rittner and Reed, 1992; Leng, 1997). These substances are associated with the lignin that is negatively correlated with protein degradability

(Kohn and Allen, 1992; Rittner and Reed, 1992). Cell wall content in legumes which does not normally appear to become limiting is between 50 and 60% of the forage DM and these which can account for rumen fill are highly associated with both rumination and chewing time among a wide range of forages (Stensig *et al.*, 1994).

2.9.1.2 Feed preparation

The manipulation of the physical form such as chopping of roughages may reduce feed wastes though not the cell wall structure (McDonald *et al.*, 1998). Nevertheless, there are varying dimensions of chop length and subsequently particle sizes whether chopping is carried out mechanically or manually. In silages, for example, O'Kiely (2001) indicated that particle lengths can range from as long as 30 to 60 cm to as short as 1 to 2 cm. Results from feeding of sheep with long and chopped rice straw indicated similar DM intake of 51 and 50 g/kgW^{0.75} respectively. However, chopping of grass silages, green forage or hay to short pieces has been shown to increase intake and reduce time of eating because the animal has less opportunity to select between the different parts of feed (O'Kiely, 2001). When long, unchopped forages are offered, animals have more time to select between stem and leaf thus more opportunity for eating materials of higher nutritive value despite increased time for eating (Minson, 1990). Grinding and pelleting is considered to increase voluntary feed intake because the processed feeds pass through the rumen at a faster rate leading to increased consumption (Schneider and Flatt, 1975). However, Minson (1967) (cited by Minson, 1990 page 167) reported that grinding and pelleting of the

protein deficient grasses (tropical) has no effect on increased intake because appetite is mostly limited by protein deficiency but not by fibre.

2.9.1.3 Nutrient density and digestibility

Forage quality is also associated with intake in such a manner that the low quality roughage is characterised by low nutrient density (Sumamal *et al.*, 2003), slow rates of breakdown and disappearance from the reticulo-rumen and consequently low voluntary intake (Fernandez *et al.*, 2003). In general, however, increase in quality also increases intake. Lyons *et al.* (1999) demonstrated that intake increases as forage digestibility increases from 40 to 80% (Figure 4). Boumont *et al.* (2003) reported, however, that with the same digestibility, voluntary intake of legumes is about 20% higher than that of grasses due to lower cell wall content. Relling (2001) also noted that the stage of maturity of pasture influences forage quality and hence selection such that digestible organic matter intake by sheep (DOMI) decreased from 60 g/kgW^{0.75}/day for young *P. maximum* in the summer to 48 g/kgW^{0.75}/day for mature *P. maximum* in the same season.

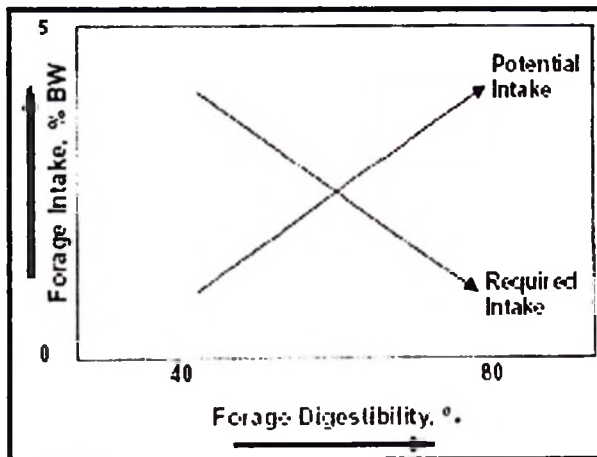


Figure 4. Relationship between forage digestibility and amount of forage ruminants can eat, and the amount of forage needed to meet nutrient requirements (as a percent body weight (BW)

Source: Lyons *et al.* (1999).

Palatability of feed that is normally assessed by choice situations (De Rosa *et al.*, 1997) affects voluntary feed intake. Studies have indicated, however, that preference depends not only on the sensory properties of the feed but also on the physical structure, which in turn influences the ease of prehension (Kenney and Black, 1984). With diets containing high proportions of roughage, intake is limited by the capacity of the reticulo-rumen and the rate of disappearance of digester from the rumen (Ketelaars and Tolkamp, 1992; Beaver, 1993).

The composition of diets such as protein content is implicated in limiting intake (Minson, 1967 as cited by Minson, 1990: 167). Low protein intake equates with a lowered digestibility of the total diet, causing a reduction in DMI and a decrease in animal performance (Kearl, 1982; Forbes, 1995). Kearl (1982) reported also that with cattle, it would be advantageous to have roughage-concentrate diets that provide 11 to 12% total protein so as to attain efficient digestion and fermentation in the

rumen when roughage-concentrate diets are fed. Equally, decreases in consumption of forages when their CP content falls below 6-8% have been reported to be due to inadequate supply of $\text{NH}_3\text{-N}$ that is important for maximum fibre digestion in the rumen (Kearl, 1982; Lyons *et al.*, 1999).

Furthermore, there is a tendency for increased feed intake with increase in herbage allowance. This increase in intake with increasing allowance of feed is associated with the fact that the animal has wider chances of selection for the most nutritious/palatable parts. Bhargava *et al.* (1998) demonstrated that blades that are more nutritious were more favoured than the less nutritious stems when barley straws were fed to sheep. Similarly, decreased bite size due to decrease in green-leaf material and increase in stemy parts with subsequent reduced intake among grazing animals has also been observed (Lyons *et al.*, 1999). In order to permit ideal selection and minimize wastes of fresh forages under zero grazing conditions, Forbes (1995) proposed to allow as much as 15% refusals from the daily offer.

Lyons *et al.* (1999) and Boumont *et al.* (2003) also reported on the role of plant characteristics on forage ingestibility and thus intake. Boumont *et al.* (2003) defined ingestibility as *the maximum quantity of the feed that can be eaten by the animal when this is supplied ad libitum as the sole feed*. The authors also noted that the ingestibility of green forage, particularly when fed indoors depends mainly on its nutritive value; fill effect and sensory properties. The decrease in ingestibility with advanced age of forage is associated with increase in fibre content (section 2.7.1). Generally, modification of ingestibility through forage conservation has been

observed whereby hay was noted to have a depressed nutritive value (Dermaquilly, 1989; Boumont *et al.*, 2003) and consequently ingestibility compared to original green grass. Likewise, ingestibility of silage resulting from similar green forage was depressed particularly if the conservation quality is poor (Dermaquilly, 1989; Boumont *et al.*, 2003).

2.9.2 Animal factors

The physiological state of the animal such as age, pregnancy and lactation as well as the species and their health status are reported to increase or decrease feed intake of an animal (Ketelaars and Tolkamp, 1992). Some reports have indicated that feed consumption will also be regulated by the rate at which absorbed nutrients are removed from circulation by processes of metabolism (Beever, 1993). Other authors (Lyons *et al.*, 1999) show that for domestic ruminant species, intake increases approximately in proportion to maintenance requirements such that for lactating and young animals with high basal metabolism and maintenance requirements an increase in feed intake is observed. Furthermore, Ketelaars and Tolkamp (1992) reported observations whereby lactating dwarf goats (ca. 20 kg) consumed 6% of their body weight when provided with roughage with DMD of about 55%. Similarly, it has been noted that intake decreases for animals in ill health and those in latest stages of pregnancy (Ferret *et al.*, 1998) and early lactation (Ferguson, 1996).

The nervous system is involved in regulating DMI through the hypothalamus in the brain. Miner (1992) and Chaillou *et al.* (2000) reported that there are centres of the

hypothalamus that are electrically stimulated to either stop or accelerate eating activity. The signal of these centres results from the physical stimulation of the stretched receptors in the wall of the stomach (Miner, 1992; Mohamed, 2003). The distension of the abomasums has also been shown to depress intake (Mohamed, 2003). Ferret *et al.* (1998) associated the changes in endocrine balance during the last weeks of pregnancy and the subsequent increased uterus volume with depression in food intake. Likewise, Boumont *et al.* (2003) noted that the volatile fatty acids (VFA) such as acetate, butyrate and propionate that are the end products of fermentation also play significant roles in processes involved in eating.

2.9.3 Environmental factors

Environmental factors such as day length, humidity and ambient temperature have profound effect on intake in domestic livestock. High temperatures (especially in tropical environments) create heat stress and are reported to depress feed intake immediately (Ketelaars and Tolcamp, 1992). The increase in intake during cold stress (particularly in temperate regions) is generally explained to be a result of increased rumen motility following an increase in energy requirement (Shafie *et al.*, 1994). High humidity associated with high ambient temperatures also depresses feed intake. After adaptation, however, heat and cold stress have opposite effects on digesta retention time, pituitary activity and basal metabolism (Shafie *et al.*, 1994).

2.10 Focal points for future research and extension based on local and complementary knowledge systems

The future focus of research and extension for improved rural livelihood may demand effective contribution of farmers' knowledge in crop and livestock production. This, however, necessitates the recognition of farmers' analytical skills and knowledge as important elements in agricultural technology. As Ravnborg (1996) puts it, these elements cannot be easily and unambiguously predetermined by research but only after scrutiny of the potentials and limitations of LKS. The strengths and weaknesses of LK and that of formal scientific knowledge in livestock feeding are shown in Table 6. It is clearly indicated from Table 6 that although farmers may be able to identify locally available feed resources, they may not have a detailed understanding on the contribution of each of the forage material (or a combination of feeds) to the productivity and health of all animals. This is equally true to 'formal research scientists' because they are unlikely to know everything about feed resources found in every production system. Therefore, the understanding of what LK and formal scientific knowledge can offer is essential so as to enhance efficient utilization of local feed resources. In other words, understanding of the strengths and / or weaknesses of each of the two knowledge systems and solving the identified weaknesses might lead to improved productivity of livestock particularly in the mixed production systems of tropical Africa.

Table 6. Complementarities of local (farmers') knowledge and formal scientific (researchers') knowledge in livestock feeding

What farmers know better	What farmers may not know better	What researchers may not know well	Researchers' contribution and role of feed evaluation in providing new information
Available resources including forages and other animal feeds	Potential use of improved, exotic or unfamiliar feeds	Contribution of familiar and unfamiliar feeds to livestock productivity under all production systems	<ul style="list-style-type: none"> ▪ Assess productivity with local feeds under specific production conditions or farming systems ▪ Assess improved feeds (selection during forage breeding programmes, treated feeds etc) ▪ Identify role / use of new feeds within existing feeding systems ▪ Compare new with existing feeds to assess potential benefits
Approximate performance of indigenous livestock on locally available feeds	How to improve performance	How to improve performance under field / farmers' conditions	<ul style="list-style-type: none"> ▪ Diagnose nutrient imbalances in diets ▪ Identify feed combinations which improve the nutrient balance of the diet

Source: Summaries from literature reviewed by the researcher (2001 –2005).

2.11 Summary of the literature reviewed

The literature reviewed indicates that there are tremendous variations in resource availability and use emanating from climatic, physical and socio-economic circumstances of different farming communities. Equally, it indicates that individual farmers and farming communities at large have a rich base of knowledge of the

locally available resources. At the same time, there exists a broad base of knowledge and techniques in animal production that were developed formally which, if appropriately applied, could lead to improved feed management and ultimately increased livestock production. Moreover, it was noted that LK within or between the farming systems could be amalgamated with modern scientific knowledge. However, amalgamating LK with formal scientific (researchers') knowledge cannot be done productively unless these two knowledge systems are effectively studied.

Therefore, this review of literature and further investigations undertaken in this thesis have, on one hand, underlined the importance of LK in the SPD and similar mixed production systems. On the other hand, all these have underscored practical aspects of LK and the congruency or discrepancy of LK with formal scientific understanding in forage evaluation. It is only when these or related systematic studies are undertaken that LK in livestock feeds and feeding systems can be directly tapped or modified for the benefit of farmers, researchers and extension agents. Ultimately, the results could be relevant to for sustainable productivity of the mixed production systems.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Overview

This chapter begins with the presentation of the conceptual model of the farming system of the study area and the conceptual framework of the study. This is followed by studies that involved both informal and formal surveys, controlled animal experiments and laboratory studies. The chapter ends with a description of organisation of all the data and approaches to their analysis.

3.2 The farming system and conceptual framework for the study

3.2.1 Conceptual model of the sugarcane-paddy-dairy (SPD) farming system

The review of secondary sources (ENRECA, 1998; Otte and Chilonda, 2003) and preliminary visits to the study area led to the generation of a conceptual model of the farming system of Turiani division. The model was designated as the *sugarcane-paddy-dairy (SPD) farming system* because of the dominant grain and plantation crops produced for both food/cash and cash respectively as well as the cattle (dairy) production component onto which LK studies for this thesis were focused (Figure 5).

3.2.1.1 Components of the system

The major crops (paddy, sugarcane and maize) and minor crops (cassava, beans and yams) grown depend on family or hired labour that is also required in attending animals under free or zero grazing systems. Crop and livestock production activities are interrelated and are at any time influenced by other factors in the production system (Figure 5). Although animal feeding rely on locally available feed resources obtained from communal rangelands, from fields after crop harvests, fallows, feed gardens and even from roadsides, there are demographic and other socio-economic factors that exert pressure on land and other natural resources pertinent to crop and livestock production components.

It is worth noting that what happens within or outside any sub-system could have tremendous effects to the whole system to which it is related (Spedding, 1995). This is noted with respect to the relationships between the crop, livestock and the socio-economic components of the farming system (Figure 5). Therefore, as it could be with the high-input high-output agricultural systems (Spedding, 1995), so it is with the low-input low-output production systems like that of Turiani division, which is a subsystem of the larger (Tanzania) agricultural system.

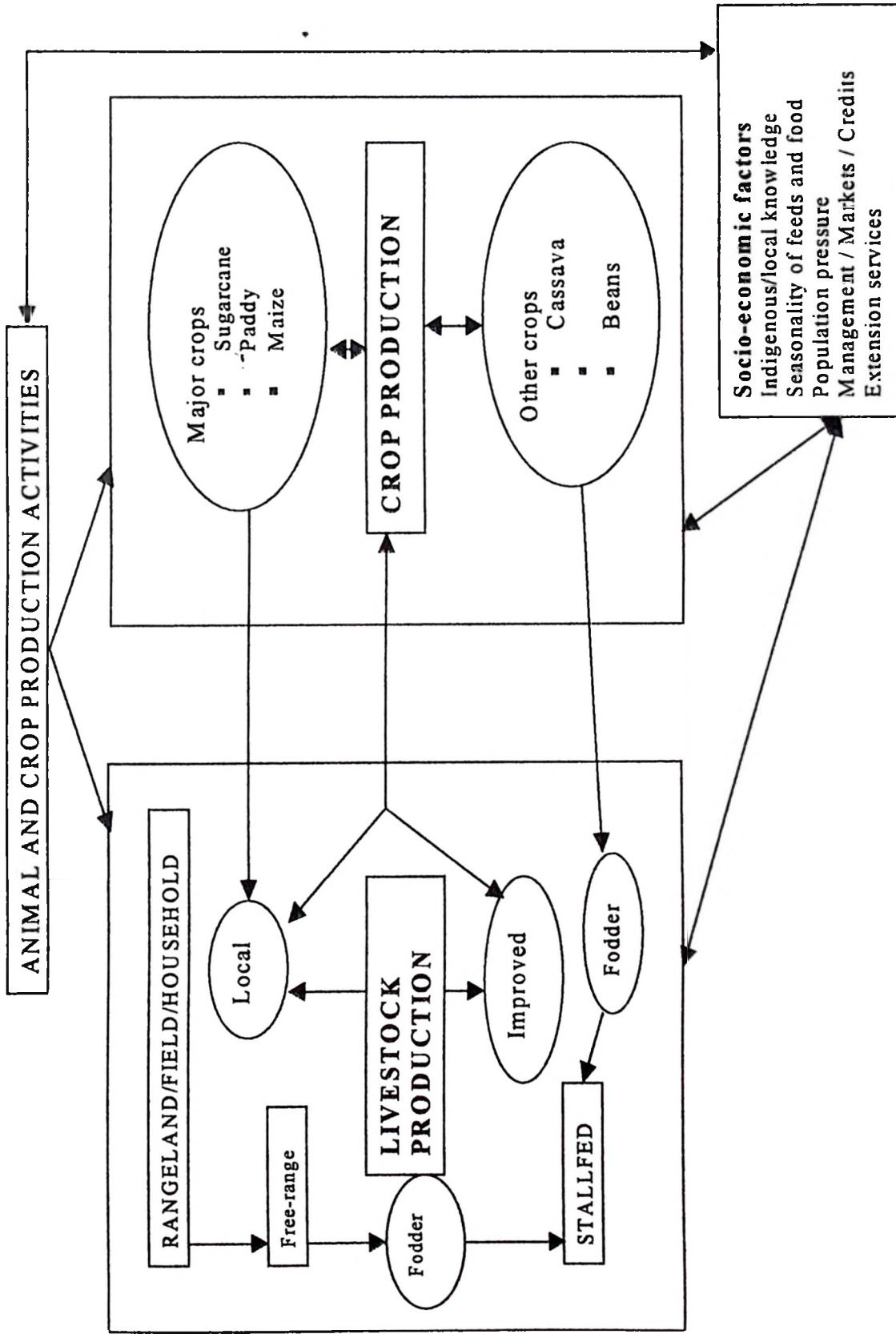


Figure 5. Conceptual model of the farming system of Turiani division

3.2.1.2 Development of the dairy production component

In the early 1990's two non-governmental organisations i.e. The Foundation for Sustainable Rural Development (SURUDE) and Heifer Project International (HPI) introduced cross-bred (Friesian x Zebu or Ayrshire x Zebu) cattle (cross-bred) in Turiani division through zero grazing practices (ENRECA, 1998). The introduction of cattle aimed at providing nutritious food (milk) for the cattle keeping families and for improving household incomes through sales of surplus milk, milk products and/or sales of live animals. The sales of surplus milk were anticipated from the introduced animals because crossbred cows (*Bos taurus* x *Bos indicus* blood) have been proved to be far more superior in milk yield than the traditional short horn zebu (TSZ) (Kishinhi, 1999; Bebe *et al.*, 2003a).

Despite the use of crossbred animals, emphasis on stall-feeding (zero grazing) and establishment of forage species {Guatemala grass (*Tripsacum laxum*) and shrubs (*Leucaena leucocephala*, *Sesbania sesban*)} were advocated as parallel packages in the existing crop production systems. The Danish International Development Agency (DANIDA) through the project on "Enhancement of Research Capacity (ENRECA)" that involved Sokoine University of Agriculture (SUA, Tanzania) and Makerere University (MU, Uganda) [(i.e. SUA-MU ENRECA Project)] had collaborated with SURUDE in executing FSR and other activities in the farming system (Petersen, 1997; Petersen *et al.*, 2000).

3.2.2 Conceptual framework of the study

In order to describe LK on available forages (grasses, forbs, tree and shrub legumes as well as crop residues) and their utilization, studies through formal and informal surveys on collective and individual opinions and activities were crucial. This is because in all on-farm or off-farm activities carried out under smallholder production settings an individual farmer is related to other farmers. Therefore, through individual and community involvements, it was anticipated that benefits, problems or detriments associated with the use of available forages would be unveiled. Earlier studies conducted among smallholder farmers in Namibia (Larsen, 2000) revealed interesting features addressed by LKS in agriculture particularly on resource management in livestock husbandry systems (Figure 6).

Therefore, the present study on LK of the nutritional and feeding value of the feed resources were based on interactive relationships between the researcher, individual farmers as well as groups of farmers (Figure 7) in the study area. At each level the interest was to learn from farmers not only about their inevitable familiarity of the locally available forages for the cattle and other livestock but also aspects in the management of these feed resources. Since all decisions and activities in many rural societies begin at a household level, it was essential to talk to the household head or his or her (adult) representative on activities and issues about the household.

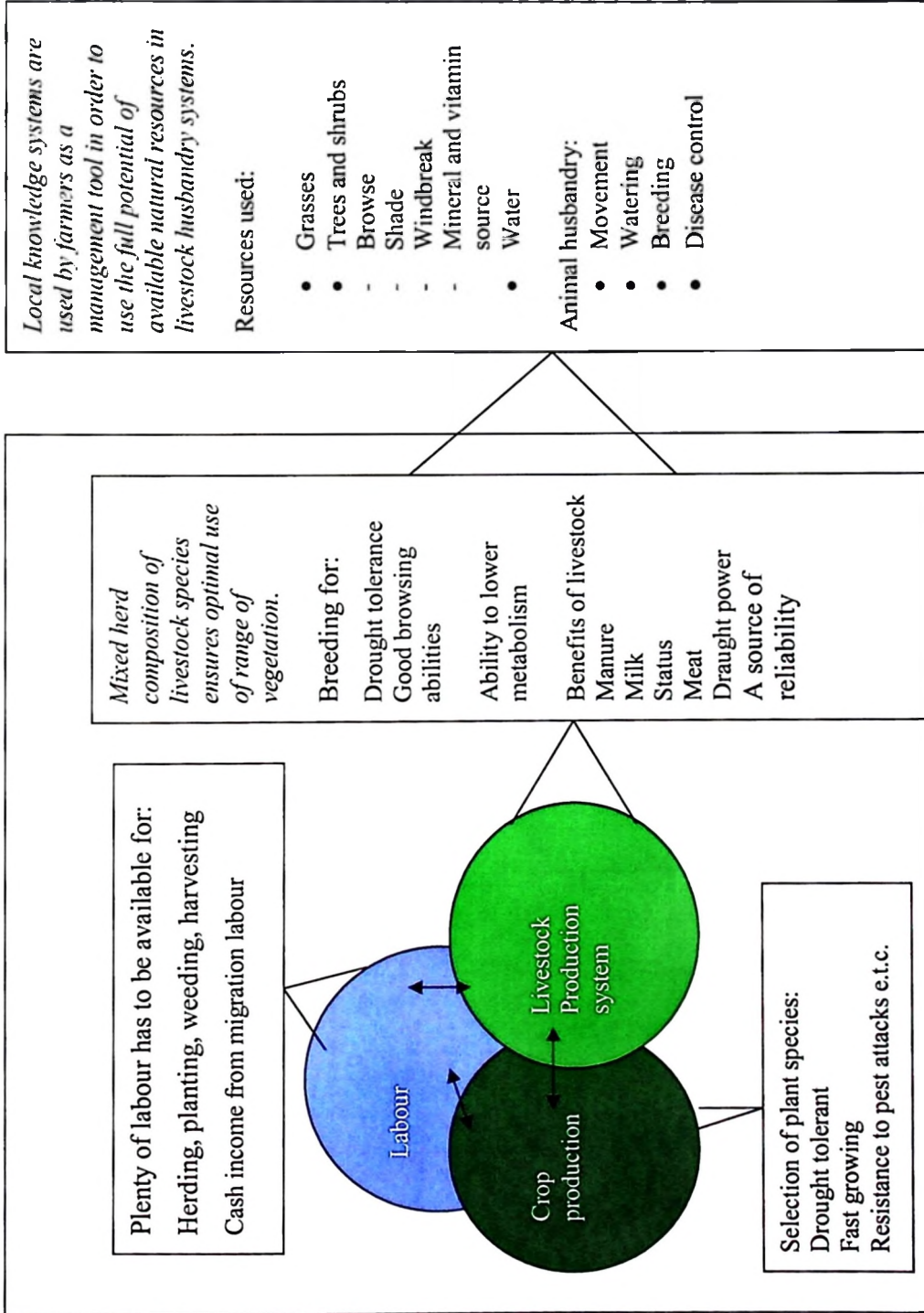


Figure 6. Small scale farming system composition in ecological uncertain environments
Source: Larsen (2000)

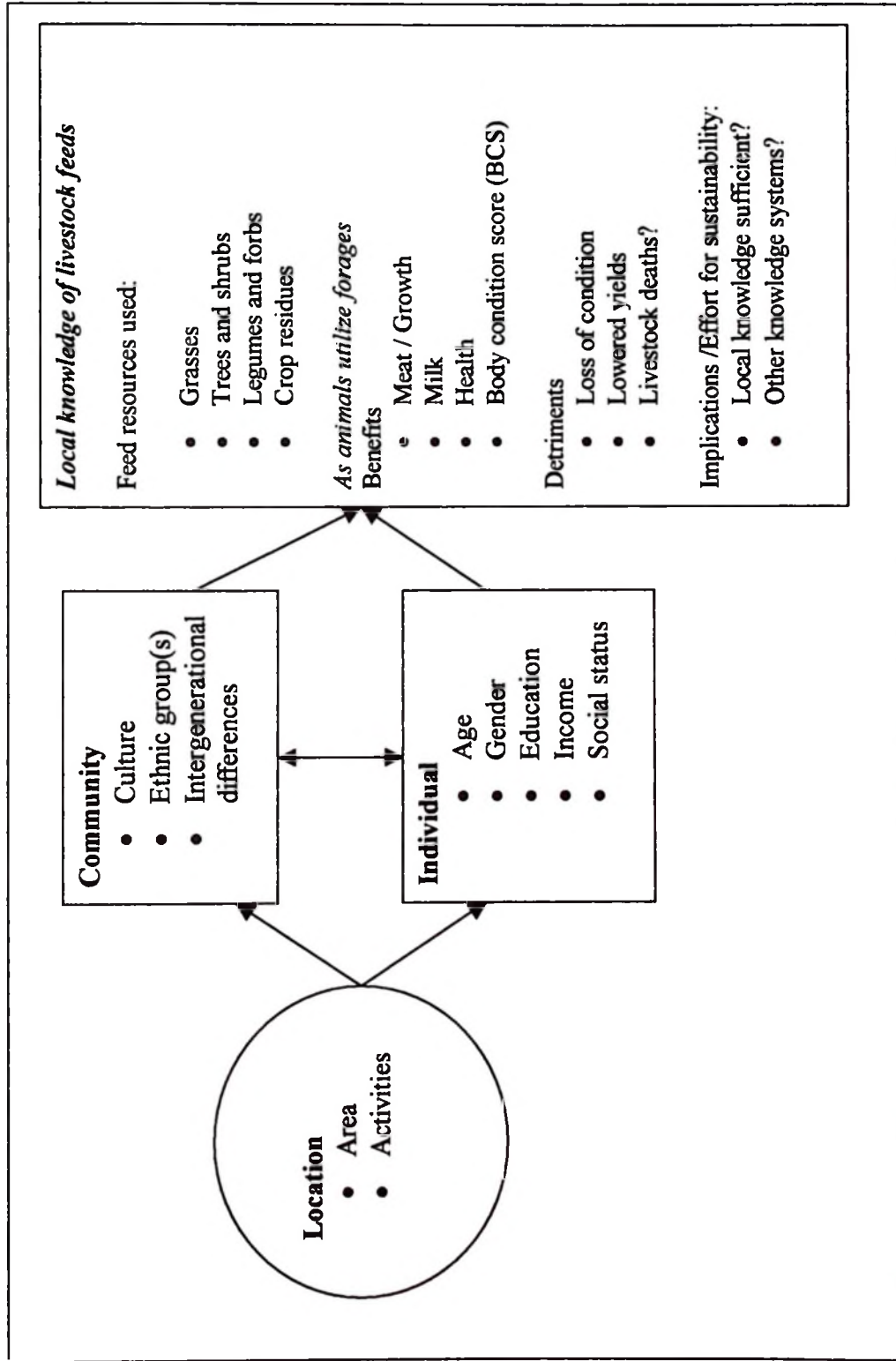


Figure 7. Conceptual framework in research on local knowledge of the nutritive value of forages in Turiani, Morogoro

3.2.3 Units of analysis

The unit of analysis included the household, which was defined by Kajembe (1994) as people in the same housing or compound usually eating from a common pot. However, it was necessary to incorporate both inter- and intra-household aspects in the use of forage resources and management of animals. The aim was to make sure that all types of community knowledge about forage qualities are represented through participatory approaches (King, 2000). In addition to considering individual knowledge through individual interviews (both informal and formal), it was also necessary to have group meetings of household heads or their representatives (e.g. spouses, adult sons and daughters and/or herdsman) at various phases of the research work. It was also imperative to consider individual respondents as units of analysis in order to have a wider view on the aspects of LK of forage qualities in the study area.

3.2.4 Quests for gap filling and sustainability

Drawing the full picture on farmers' knowledge on utilization of available forages for cattle was crucial in order to ascertain the prevailing LKS in the management and use of forages. It was equally essential to determine any existing gaps that could be filled by other stakeholders including research and / or extension for sustainable production of livestock (cattle) kept in the study area (Figure 7). These were achieved in four phases through specific studies conducted therein (section 3.3.2.1).

3.3 Methodology

3.3.1 Research sites

Except for the analytical-laboratory based studies that were conducted at the Department of Animal Science and Production (DASP), Sokoine University of Agriculture, all field studies were conducted in Turiani division, Mvomero district about 100 kilometres North of Morogoro municipality (Figure 8).

3.3.1.1 Geographical features and villages involved in the study

Turiani division lies between longitude 37°10' and 38°31'E and from latitudes 5°5' to 7°4'S. It is subdivided into five administrative wards namely Diongoya, Mhonda, Mtibwa, Kanga and Sungaji. The Nguu Mountains which form a part of the blocks of the Tanzania's Eastern Arc Mountains run over the Western through the Northern side of the division leading to varying altitudes in the area. For example, many areas in Mtibwa and Sungaji wards lie at an altitude as low as 372 metres above sea level (m.a.s.l) whereas in some parts of Mhonda and Kanga wards the altitude is as high as over 600 m.a.s.l. A total of ten villages were involved in various phases of the study. These were Lusanga and Manyinga villages in Diongoya ward; Mhonda and Kichangani villages in Mhonda ward; Madizini, Lungo, Kidudwe and Kunkhe villages in Mtibwa ward and Kilimanjaro and Kisala villages in Sungaji ward.

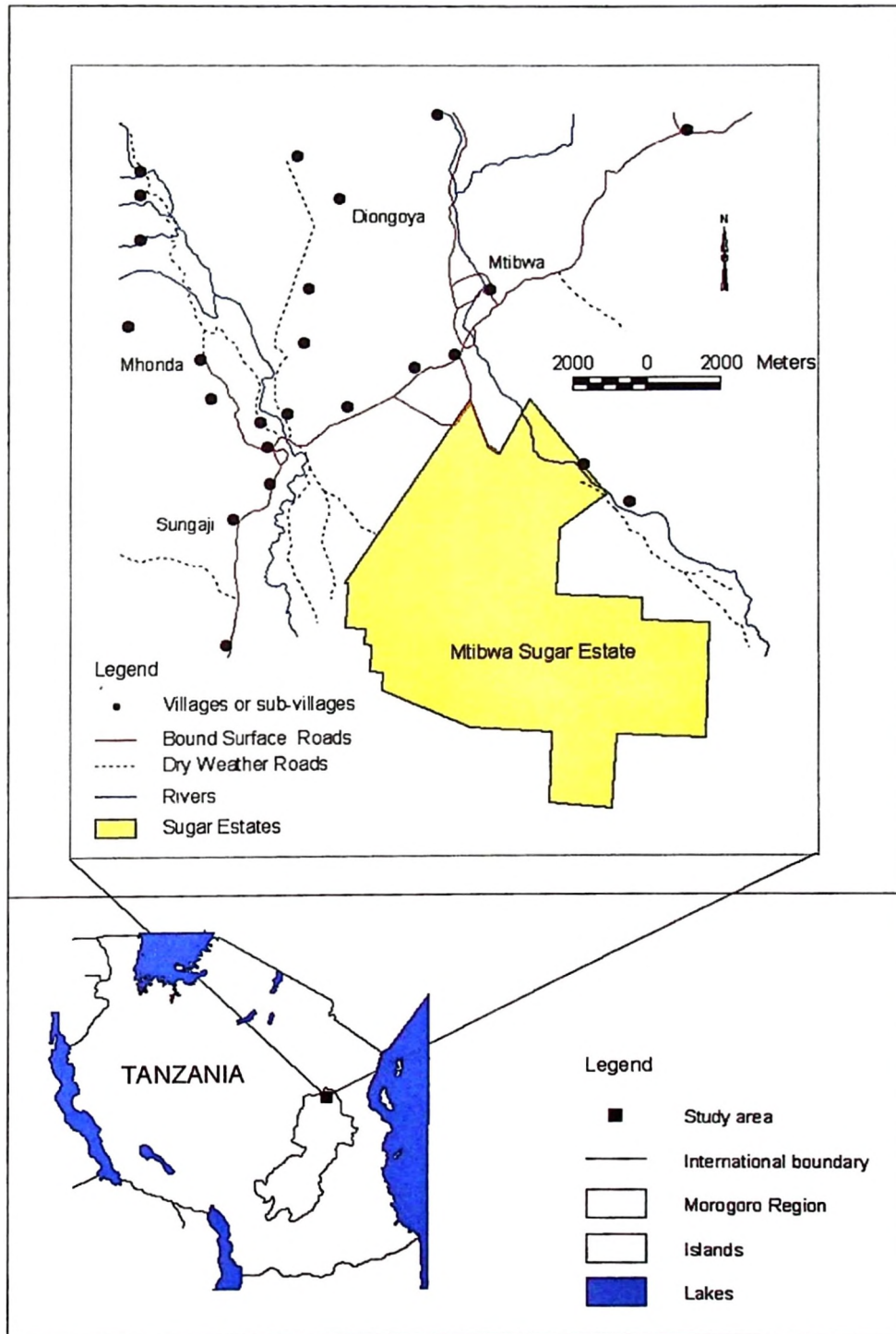


Figure 8. Map of Tanzania showing the study sites in Turiani division, Morogoro.

It was imperative to obtain specific and general understanding of local forages from areas where livestock (cattle) are kept. Therefore, the research sites were selected based on the fact that a village had some cattle keeping activities (section 3.4.1).

3.3.1.2 Climatic conditions of the study area

Turiani division has a bimodal type of rainfall with short rains between October and December and long rains between March and May. The two rainy seasons are marked with rainfall peaks in December and April respectively. The five-year rainfall collected at Mtibwa meteorological station from 1999 through the study period indicated variations in patterns of rainfall distribution over years (Figure 9). The average monthly and annual rainfall of about 95mm and 800mm respectively were recorded during this period. Mean monthly maximum and minimum temperatures of about 30°C and 20°C respectively were recorded as indicated in the five-year data (Figure 10).

In most cases the division has high humidity of up to 80% (Figure 11) and characteristics of the sub-humid agro ecological zonation. The sub-humid agro ecological zones are defined as zones where the growing period of plants is between 180 and 270 days (Lead, 2002). Unlike in zones where quantity of pasture could limit livestock husbandry, the limitation of livestock farming in the referred sub humid zone may be more on the quality than the quantity of pastures available.

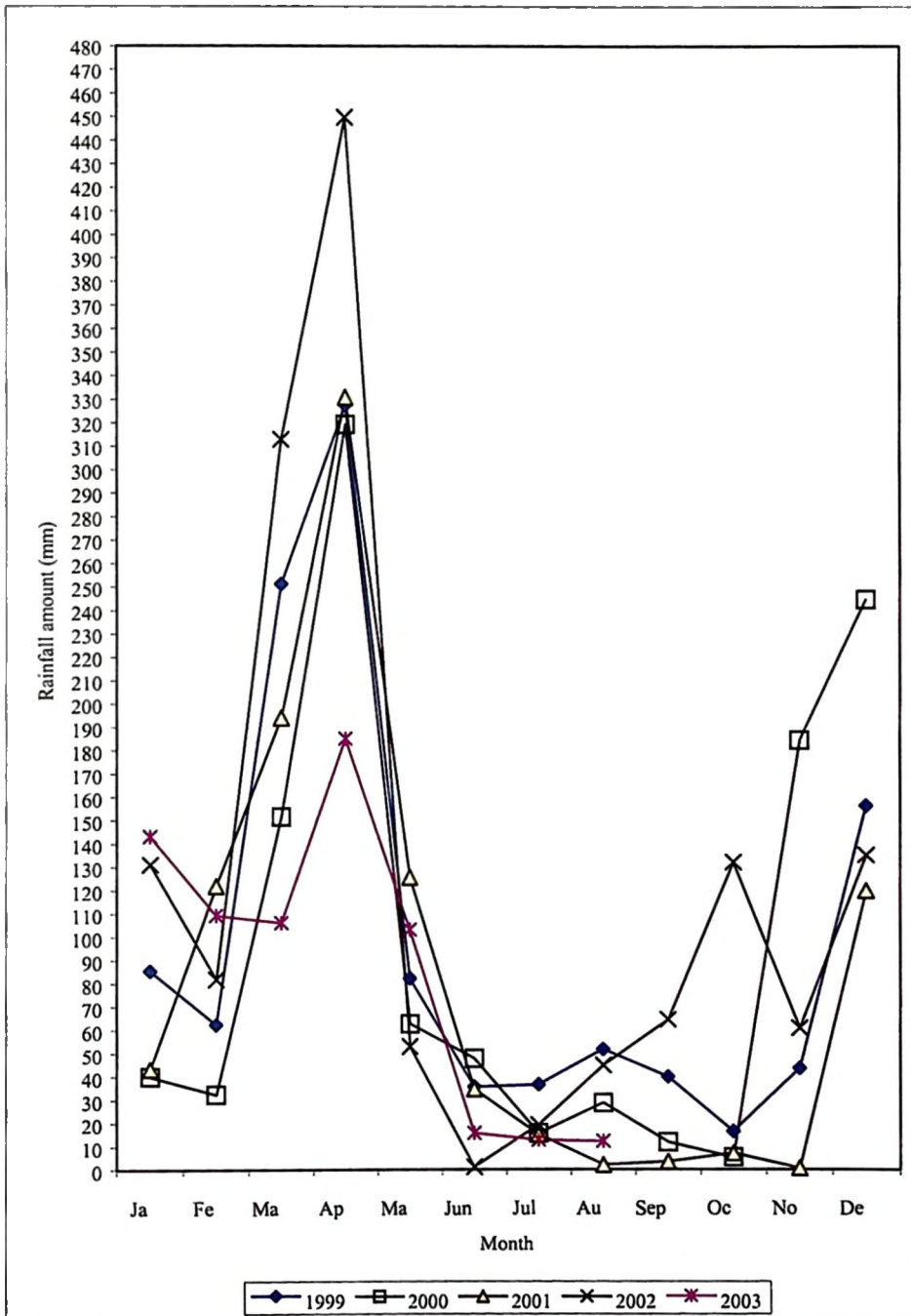


Figure 9. Monthly rainfall (mm) in Turiani division 1999 – 2003.
Source: Mtibwa Sugar weather station (2003)

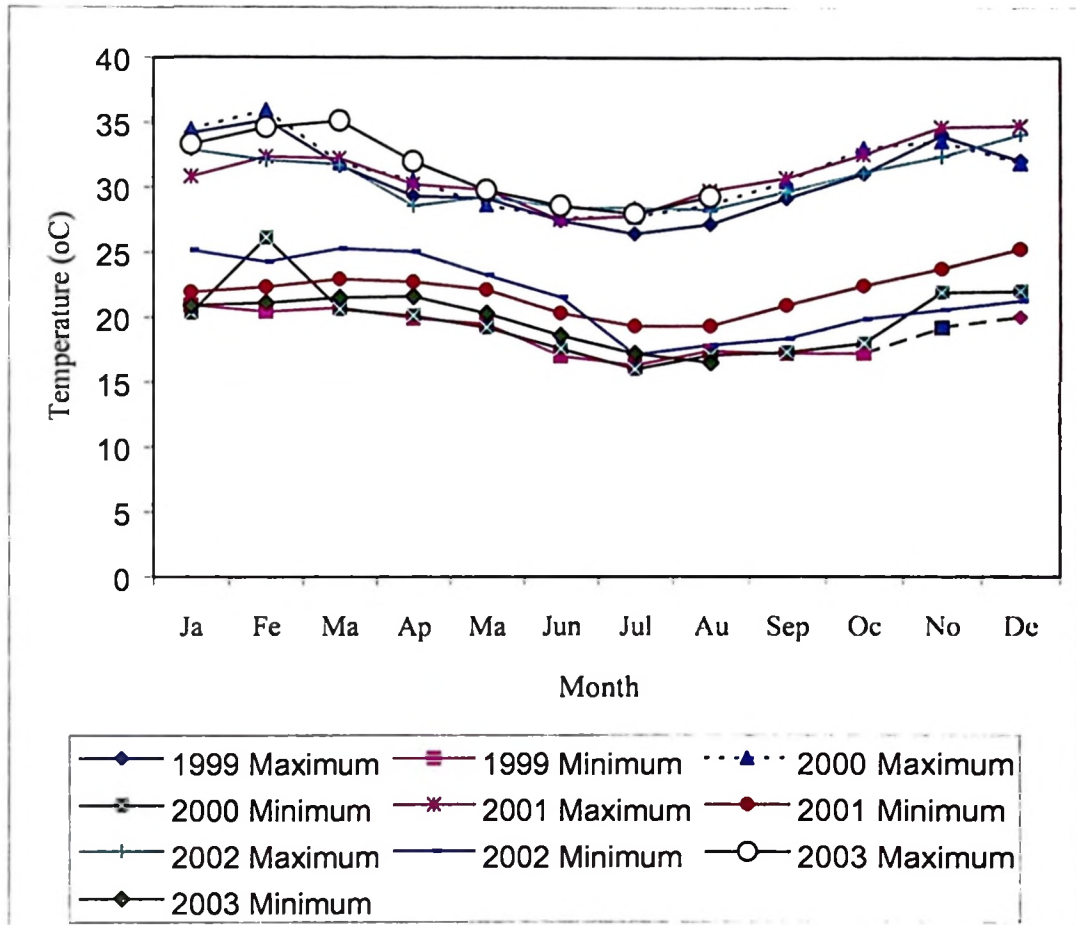


Figure 10. Maximum and minimum temperatures in Turiani (°C) 1999 – 2003
Source: Mtibwa Sugar weather station (2003)

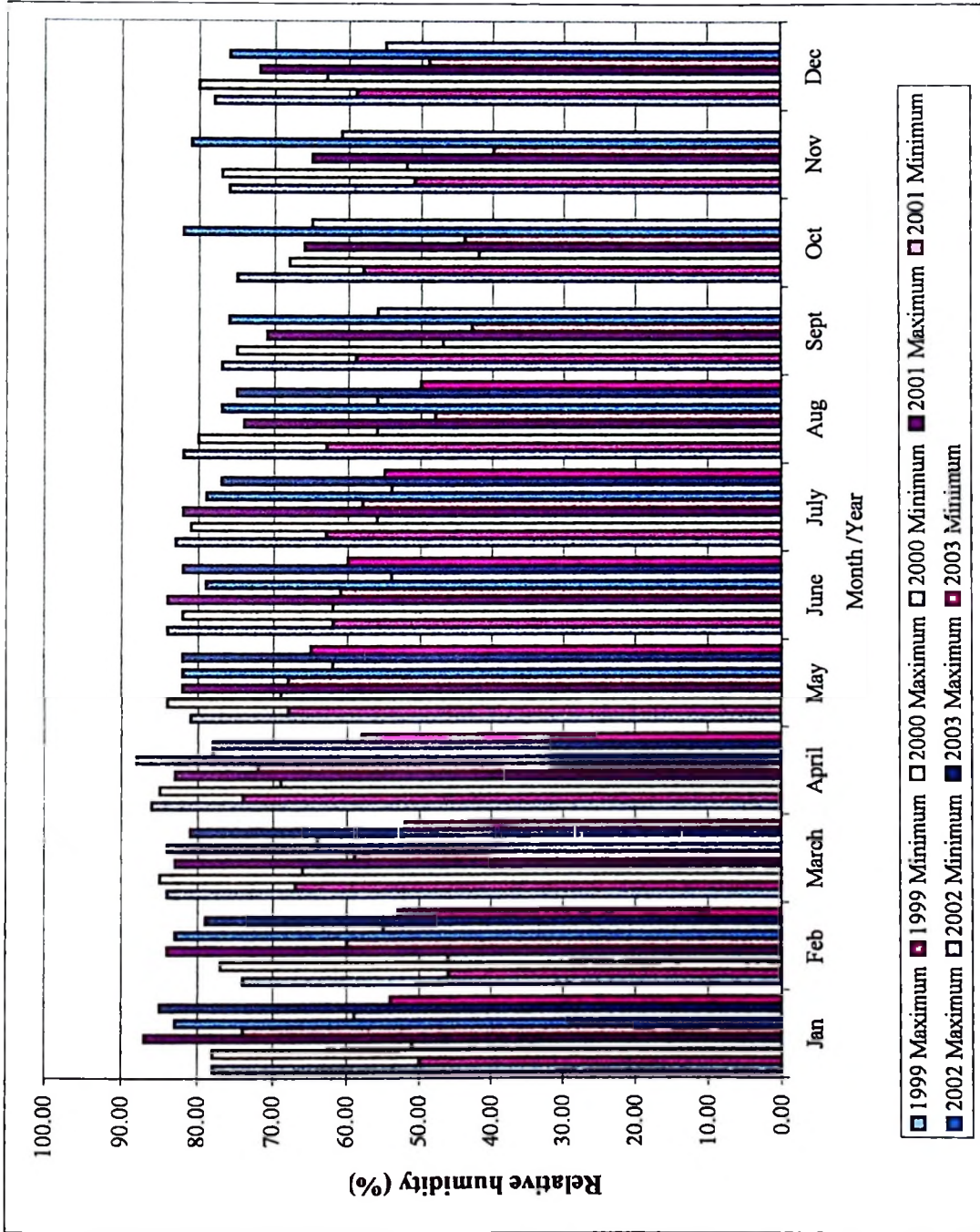


Figure 11. Maximum and minimum relative humidity (%) in Turiani 1999 – 2003
 Source: Mtibwa Sugar weather station (2003)

3.3.2 Research phases and design

3.3.2.1 Research phases

The study was undertaken in four phases comprising of field visits and controlled animal experiments.

3.3.2.1.1 Reconnaissance survey phase

This was an initial and quick tour of the division in which an overview of the surroundings and farm activities was undertaken. The survey was carried out in August 2001. With the assistance of extension workers, the researcher managed to visit some ward and village executive officers as well as some household heads. This phase was crucial, not only for providing an insight of the natural features (hills, mountains, valleys, rivers) and infrastructures (roads and pathways) but also for getting acquainted with physical and the social environment of the study area.

3.3.2.1.2 Informal surveys and topical PRA phase

Informal surveys and PRA phase comprised of activities carried out from February to April 2002. Focused group discussions were undertaken in this phase too. Initial contacts were made with village governments, farmers' group leaders and extension workers in order to organize meetings for focused group discussions.

3.3.2.1.3 Formal surveys and forage sampling phase

This research phase ran from May 2002 to April 2003 whereby single household (cross-sectional) surveys and repeated (longitudinal) visits/interviews were done. Sampling of forages used was concurrently undertaken. Participant observation as a method of data collection was also employed in this and other phases of the research.

3.3.2.1.4 Feeding trials phase

Feeding trials were conducted as from March to July 2003. Two major experiments were conducted at the Centre for Sustainable Rural Development (SURUDE) (Latitude 06°17'S and longitude 37°68'E; 372 m.a.s.l) located in Lungo village, Turiani division, Morogoro, Tanzania. In the first experiment, two trials were carried out whose aim was to investigate preference in consumption of forages locally found in the study area. Four growing bull calves were used as detailed in section 3.4.4.1. In the second experiment twenty crossbred bull calves were used whereby forage intake and growth performance were assessed (Section 3.4.4.2).

3.3.2.2 Research designs

3.3.2.2.1 Cross-sectional design

The cross-sectional design was adopted in the single household survey conducted in ten villages. This could enable the researcher to have a description of phenomena in

the farming system at a single point in time (Gujarati, 1995). It was also imperative to adopt the design because the types of data obtained were expected to give valuable description of parameters of the FS in subsequent phases of the study (Babbie, 1973).

3.3.2.2.2 Longitudinal design

The longitudinal design in the category of Panel studies (Gujarati, 1995) was adopted in phase three of the study whereby the same respondents (panel) were interviewed in four subsequent times (seasons). This design was selected because of the interest to capture any seasonal variations for data collected at different times of the year. The survey was done in each of the *four interlocking seasons* (Table 7) at intervals of approximately two months. The two-month interval between one interview session and another was selected in order to reduce the problem of attrition (Babbie, 1973) since it was assumed that it would be possible to contact the same respondents in this short time interval. The longitudinal surveys were done in Lusanga village in Diongoya ward; Kichangani village in Mhonda ward and Lungo and Kilimanjaro villages in Mtibwa and Sungaji wards respectively.

Table 7. Seasons during longitudinal survey and sampling of forages

S. No.	Season description	Survey month	Sampling month	Year
1	Cool / Dry	July / August	August	2002
2	Dry	September / October	October	2002
3	Short rain	December / January	January	2003
4	Long rain	April / May	May	2003

Source: Author's research plan (2002)

3.3.2.2.3 Completely randomised design (CRD)

A completely randomised design (CRD) was used during the intake (ingestibility) and growth experiments whereby five growing bull calves were allocated to each of the four treatment diets. The CRD was also employed during the *in sacco* degradability studies of forages and concentrate samples.

3.3.2.2.4 Latin square design

A 4 x 4 Latin square design was used in the two feed preference trials (Table 8 (a) and (b)). The four crossbred bull calves of approximately the same age and weight were used to measure short-term DM intake of four forage grasses (TREATMENTS). The treatments were assigned in four consecutive days of the data collection period (ROWS) in four sequential orders (COLUMNS). Each of the four orders lasted for 15 minutes. The order of offer for the treatment was varied each day. The experiments involved 7 days of acclimatization period before the start of the first trial (the 4 days of the data collection) while the second trial (also 4 days of the data collection) followed immediately after the first trial.

Table 8 (a). Daily order of offering forages species to four experimental animals during the single forage preference studies

Animal No	Day	Order of offer / Treatments			
		1	2	3	4
1	1	T3	T4	T2	T1
2	1	T3	T4	T2	T1
3	1	T3	T4	T2	T1
4	1	T3	T4	T2	T1
1	2	T1	T2	T3	T4
2	2	T1	T2	T3	T4
3	2	T1	T2	T3	T4
4	2	T1	T2	T3	T4
1	3	T4	T3	T1	T2
2	3	T4	T3	T1	T2
3	3	T4	T3	T1	T2
4	3	T4	T3	T1	T2
1	4	T2	T1	T4	T3
2	4	T2	T1	T4	T3
3	4	T2	T1	T4	T3
4	4	T2	T1	T4	T3

Treatments T1 = *Panicum maximum* T2 = *Panicum trichocladum*
T3 = *Pennisetum purpureum* T4 = *Rottboelia cochinchinensis*

Table 8 (b). Daily order of offering forages species to four experimental animals during the mixed forage preference studies

Animal No	Day	Order of offer / Treatments			
		1	2	3	4
1	1	M13	M14	M12	M11
2	1	M13	M14	M12	M11
3	1	M13	M14	M12	M11
4	1	M13	M14	M12	M11
1	2	M11	M12	M13	M14
2	2	M11	M12	M13	M14
3	2	M11	M12	M13	M14
4	2	M11	M12	M13	M14
1	3	M14	M13	M11	M12
2	3	M14	M13	M11	M12
3	3	M14	M13	M11	M12
4	3	M14	M13	M11	M12
1	4	M12	M11	M14	M13
2	4	M12	M11	M14	M13
3	4	M12	M11	M14	M13
4	4	M12	M11	M14	M13

Treatments: M11 = *Panicum maximum* + *Panicum trichocladum*
M12 = *Panicum maximum* + *Rottboelia cochinchinensis*
M13 = *Panicum trichocladum* + *Rottboelia cochinchinensis*
M14 = *Pennisetum purpureum* + *Panicum trichocladum*

3.4 Data collection

3.4.1 Sampling procedure and sampling frame in survey studies

3.4.1.1 Sampling procedure

The purposive sampling procedure was applied in selecting villages and respondents during both cross-sectional and longitudinal surveys. As indicated by Selltiz *et al.* (1959) a common strategy of purposive sampling is to pick cases that are judged to be typical of the population in which the researcher is interested. Therefore, the study

was limited to seeking knowledge from farmers with experience in livestock husbandry. Since the farmer's knowledge of locally available forages (for cattle) was the focus of the study, it was imperative to have cattle keeping as a criterion for sampling. Moreover, it was not all villages in Turiani division where cattle were kept. Therefore, it was more relevant to focus not only on villages where cattle were found but also on households that were known to have the animals.

3.4.1.2 Sampling frame

The sampling frame consisted of farmers (households) with cattle and those who had no cattle on the survey date but had been keeping cattle in the last 12 months (Table 9). The latter was considered an appropriate step on the assumption that even though the farmer would not be keeping the animals on the day of the visit, the valuable experience and understanding gathered through keeping the animals could still be tapped. Thus, the researcher constructed the sampling frame with the assistance of extension workers, village secretary or chairperson and leaders of farmer groups (where the groups existed).

3.4.1.3 Sample size

The selection of respondents (households) from each village was based on equation (ii) according to the formula of Boyd *et al.* (1981) as cited by Ishengoma (1998: 187):

$$n / N \times 100 = C \dots\dots\dots \text{Equation (ii).}$$

where:

C = figure \geq 5% of the village household population

N = Total number of households in the village (household that own cattle)

n = number of selected households

In this case C was expected to be 45% and cover 129 households (Table 9) but the actual sample size was of 125 households accounting for 43% of the number of households with cattle (Table 10). This sample size was, however, well above one proposed by the Farm-Level Applied Research Methods in Eastern and Southern Africa (FARMESA) that a sample size of 80 – 120 respondents was adequate for most socio-economic studies (Matata *et al.*, 2001). Furthermore, interviewees were picked at random from pieces of papers bearing names of household heads. The papers were first shuffled before picking a name. This continued until the number of people to be interviewed in a locality was achieved. On the day of the interview the respondent was a household head (Hh) or an adult (above 18 years) who was nominated by the Hh.

A total of 30 farmers were randomly selected and interviewed during the longitudinal survey. This was 24% of the total number of farmers interviewed in the cross-sectional study. The characteristics of the respondents in this survey are summarised in Table 11.

Table 9. Number of cattle and households in study villages March 2002

Ward	Village	No. of Hh	No. of cattle	No. HhC	Sample Hh
Diongoya	Lusanga	963	115	37	17
	Manyinga	801	77	28	13
Mhonda	Mhonda	518	42	21	9
	Kichangani	482	80	51	23
Mtibwa	Madizini	1051	69	12	5
	Lungo	185	155	80	36
	Kidudwe	1380	24	20	9
	Kunkhe	614	35	12	5
Sungaji	Kilimanjaro	518	38	15	7
	Kisala	347	3	12	5
Total		6859	638	288	129

Hh = households

*HhC = Household with cattle during the survey or 12 months prior the survey,

Source: Village Offices / Extension reports (2002)

Table 10. Households in selected wards and villages of Turiani division

Ward	Village	No of Hh interviewed	% of total Hh interviewed	Sampled Hh (% HhC)*
Diongoya	Lusanga	17	13.6	45.95
	Manyinga	13	10.4	46.43
Mhonda	Mhonda	9	7.2	42.86
	Kichangani	23	18.4	45.10
Mtibwa	Madizi	5	4.0	41.67
	Lungo	34	27.2	42.50
	Kidudwe	7	5.6	35.00
	Kunkhe	6	4.8	50.00
Sungaji	Kilimanjaro	6	4.8	40.00
	Kisala	5	4.0	41.67
Total		125	100.0	43.12**

*HhC = Household with cattle during or 12 months before the survey (Refer Table 7)

** Average percentage

Source: Survey data (2002)

Table 11. Characteristics of respondents in the longitudinal survey

Characteristics		Percent (N = 30)
Sex	Male	60.0
	Female	40.0
Age (Years)	15 – 30	20.0
	31 – 45	46.7
	≥ 46	33.3
Herd size (Cows)	≤ 3	80
	> 3	20

Source: Survey data (2002)

3.4.2 Forage sampling

3.4.2.1 Sampling during longitudinal survey

Samples of feeds that had been harvested for feeding on the day of the interview were collected from two farmers (farms) who were randomly selected from each of the four wards visited. The whole top of the plant (green leaf + stem) that was normally harvested (for grasses, legumes and forbs) and leaves and tender stems and twigs (for trees / shrubs) were taken. Plant parts that were diseased and wilted were discarded. Each forage species was chopped on farm with a pair of scissors. Two sub-samples were packed in paper bags and pre-dried indoors prior to further processing and analysis for chemical and nutritive values at DASP.

3.4.2.2 Sampling during feeding experiments

Sampling of offered and refused forages was done every morning and the following morning respectively. The samples were kept in polyethylene bags and transported to

Mtibwa Sugar Estates (MSE) laboratories for drying prior to chemical analyses at DASP laboratories.

3.4.3 Qualitative and quantitative data collection

3.4.3.1 Participant observation

Participant observation was adopted to serve two major purposes. Firstly, it was applied in an exploratory fashion to gain insights that were later tested by other techniques (Selltiz *et al.*, 1959). Secondly, it was intended *to gather supplementary data* that could qualify and help to interpret findings obtained by other techniques (Selltiz *et al.*, 1959; King, 2000). The method involved observation of the community, farmer groups, households and individuals in farm and off-farm activities. This went along with informal and formal discussions that were held with stakeholders regarding these activities. Distribution and use of resources such as cropping land, water, housing, animal feeding and general management of cattle were also noted. A prolonged stay in the villages enhanced observation during the research period. Living in Lungo village during the study period also helped to create rapport with farmers and gain their confidence in subsequent research activities. At the same time, the Geographical Positioning System (GPS) (12XL 12 Channel, Germin Olathe, KS, USA) was used to record waypoints for 38 households and other sites randomly selected during the visits.

3.4.3.2 Participatory Rural Appraisal (PRA)

Participatory Rural Appraisal (PRA) sessions were held and centred on *local knowledge of the forages for ruminants (cattle)* (topical PRA). Active involvement of local people in reaching consensus on points discussed was adhered to. It was the researcher's obligation to 'hand in the stick to the local community members' and facilitate the discussion (Tegnäs, 1993; Plate 1). Thus in these PRA sessions groups of eight to twelve (8 – 12) farmers were formed, one in each of the four selected villages (Table 12). Tools suitable for data collection (direct observation, review of secondary sources, semi-structured interviewing) and those used for both information gathering and analysis (pairwise and matrix ranking) were employed to select forages and criteria used by farmers in the description of the value of such materials when fed to cattle. Different species of forages were categorised in four main groups namely forage grasses, forage legumes, trees / shrubs and crop residues. Issues related to their uses i.e. seasonal distribution, availability and acceptability by the animals were also discussed based on a checklist (Appendix 1(a)). Supplementary feeds such as local crop by products and commercial supplements were also noted.

During the single household survey and PRA activities the common grass forages found in the SPD system were *Panicum maximum*, *Panicum trichocladum*, *Pennisetum purpureum*, *Rottboelia cochinchinensis*, *Trypsacum laxum*, *Cynodon* spp and *Digitaria* spp. In the individual in-depth interviews these were discussed and rated on the basis of local criteria of quality assessment.

The criteria had been identified in participatory rural appraisal (PRA) sessions held five months before the first round of surveys. These criteria (regardless of the order of their importance or otherwise) were:

1. Preference by cattle [how craved for on offer]
2. High (increase in milk yield) [based on short term observations e.g. daily]
3. Stomach fill (determined through visual observation – size of belly and quantity of remaining forages)
4. Availability at the time of the survey and throughout the season
5. Absence of feeding disorders [no diarrhea or bloat]
6. Quality of milk produced [more cream / less whey]
7. Healthy animal [associated with general condition on continued feeding] and
8. Easiness in cut and carry (Convenience).

The commonly used legumes and forbs were also evaluated on a similar basis. These were *Macroptilium atropurpureum*, *Vigna pubescens*, *Ipomea aquatica*, *Commelina africana* and *Mucuna pruriens*. All the grasses, legumes and forbs were evaluated based on four point ordinal responses:

1 = very poor

2 = poor

3 = good and

4 = very good, against quality criteria as defined by the stakeholders.

This wide scale was adopted in order to allow flexibility during discussion. The flexibility in acquiring knowledge from farmers was insisted not only because the interest was on forage utilization but also because knowledge acquired could also be used flexibly for a range of purposes, including those that were not evident prior to its gathering. Sinclair and Walker (1998) insisted on the need for flexibility in the course of LK studies among smallholder farmers.

No further attempt was done to evaluate other forages or feeds beyond local grasses and legumes/forbs because of a need for critical evaluations of LK for the selected categories. Nevertheless, most of the trees/shrubs, for example, that were commonly found were exogenous (see Table 21).

3.4.3.3 Questionnaires

The questionnaire for single household survey was developed in such a way that it contained both factual and opinion questions, with a mixture of both open and closed ended questions. This questionnaire (Appendix 2) was **pre-tested** to 20% of the target sample.

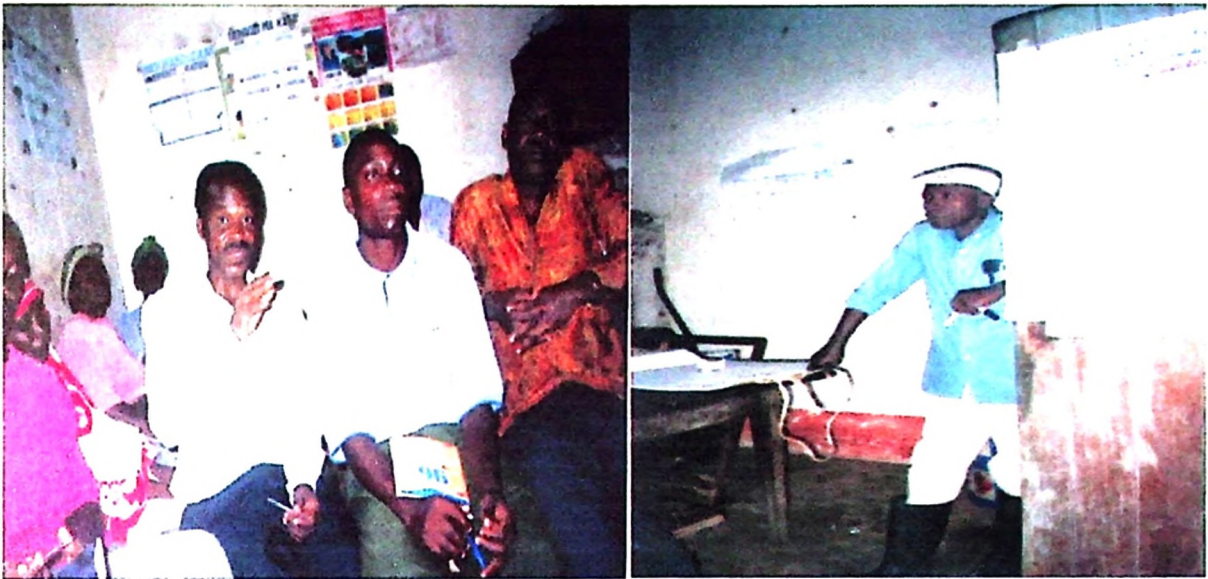


Plate 1. "Handing over the stick": A participant in a PRA session (right) leading discussion in Kichangani village while the researcher (not pictured) follows discussion.

The questionnaire used during the longitudinal survey was the same in all the four visits and was equally translated and administered in Kiswahili, the language frequently spoken in the study area (Appendix 3). This was developed after the single household interviews and several weeks of stay in the villages. The questionnaire was also pre-tested to 20% of the target sample prior to its administration.

Table 12. Participants in focused group interviews in four Turiani villages

Village	Total attendance*	Male*	Female*
Kichangani	9 (100)	6 (66.67)	3 (33.33)
Manyinga	8 (100)	5 (62.50)	3 (38.50)
Lungo	12 (100)	10 (83.33)	2 (16.67)
Kidudwe	10 (100)	6 (60.00)	4 (40.00)
Grand total	39 (100)	27 (69.23)	12 (30.77)

*Numbers in parentheses show percentage of attendance

Source: Survey data (2002)

3.4.3.4 Language and terminology

Kiswahili, the Tanzania's national language spoken almost in every corner of the country was used during discussion with individual farmers or with farmers in groups. Vernacular terminologies (*Chagga, Kaguru, Nguu* and *Pare*) were also applied when respondents wanted to stress points related to forage species and their utilization (e.g. their respective feeding values). In this case, therefore, translation of a term from a tribal language into *Kiswahili* language was sought sooner or later from extension workers, key informants or other farmers by the researcher. When a participant used a tribal language during a group discussion, explanation was requested from him/her and consensus of what was the meaning of a terminology was sought among all members in the group. This approach was used so as to allow for free expression and contribution from as many participants as possible.

Recording of the interviews was done through writing down the proceedings at the time of the interview (cf Questionnaires). In very few cases, however, tape recording of discussions was done. These were later transcribed and analysed with respect to general goals of the interviews. Field identification of forages was done using local nomenclature, but apart from that, further identification and binomial nomenclature was done with the assistance from a pasture specialist at Livestock Production Research Institute (LPRI, Mpwapwa, Tanzania). Field guides and other publications (Terry and Michieka, 1987; Skerman *et al.*, 1988; Legère, 2003) were also used in the process. Interpretation and confirmation of terminology and other expressions were done based on linguistic literature (Legère, 2003; Kamusi, 2004).

3.4.3.5 Laboratory and other animal based experiments

3.4.3.5.1 Chemical composition

Dry matter (DM), crude protein (CP) and ash (Ash) were determined according to standard procedures of AOAC (1990). Acid and Neutral detergent fibre (ADF and NDF) were analysed using procedures of Van Soest *et al.* (1991).

3.4.3.5.2 *In vitro* dry mater and organic matter digestibility

In vitro DM digestibility (IVDMD) and OM digestibility (IVOMD) of samples collected during the field surveys were determined. Samples were ground with a laboratory mill (Christy Hunt Type 8, Christy hunt Engineering Ltd, England) using a 1-mm sieve. Rumen liquor was collected from individually penned fistulated dry cows. These were the same cows used for *in sacco* studies (Section 3.4.3.5.4.). The rumen liquor was collected before the morning feeding. It was filtered through four layers of surgical gauze into the conical flask submerged in one of two stationary water bath kept at 37°C. The two stationary water baths (Grant Sub28 - Grant Instruments (Cambridge), England and Precision, Jouan, Inc. Winchester, Virginia, USA) were used for incubating the samples. Duplicate tubes containing approximately 0.5gDM of each sample were incubated in water baths maintained at 37°C based on the Tilley and Terry (1963) procedure. Incubation started at 10.00 a.m of the designated day. During the first stage of incubation with rumen fluid, sample tubes were hand shaken every 2 hours from 12.00 hours to 24.00 hours in the first

day and 8.00 hours to 24 hours in the second day of incubation. There was no shaking at all during the second stage of pepsin digestion. Other processes continued based on procedures of Tilley and Terry (1963).

3.4.3.5.3 Energy content

The *in vitro* dry matter digestibility (IVDMD%) values were converted to digestible organic matter in the dry matter (DOMD%) (Equation iii) which was later used to calculate values for metabolizable energy (ME) concentrations (MJ/kgDM) (equation iv) according to MAFF (1975) (cited by Bwire *et al.*, 2003 page 96). For the concentrate supplements used, ME was estimated based on equation (v) also according to MAFF (1975) (cited by Bwire *et al.*, 2003 page 96).

$$\text{DOMD\%} = (0.98 \times \text{IVDMD}) - 4.8 \dots\dots\dots \text{Equation (iii) and}$$

$$\text{ME MJ/kg DM} = 0.15 \times \text{DOMD} \dots\dots\dots \text{Equation (iv)}$$

$$\text{ME (MJ/kgDM)} = 0.012\text{CP} + 0.031\text{EE} + 0.005\text{CF} + 0.014\text{NFE} \dots \text{Equation (v)}.$$

3.4.3.5.4 Rumen degradability of dry matter

The *in sacco* technique (Ørskov and McDonald, 1979; Huntington and Givens 1995) was used to study DM degradability for samples of feeds used during the growth experiment (Section 3.4.4.2). Three mature fistulated cows maintained at a 60:40 hay concentrate ratio were used. The hay consisted of mixtures of *Chloris gayana*, *Brachiaria brizantha* and *Bothriochloa inculpta* and was harvested from swards established at the University farms five years earlier. The swards had been subjected

to yearly hay harvests without fertilization. The hay used had been harvested at the mature stage at the end of the 2002/2003 long rainy season (May / June) using a reciprocating mower, then baled after sun drying in the field for three consecutive days. It was stored in shaded hay barns to the time of feeding.

Bags containing approximately 2 gDM of each of the test forages were inserted in the rumen for periods of 0, 6, 12, 24, 48, 72, 96 and 120 hours. On the other hand, the supplement ingredients and the respective concentrate mixture were incubated for 0, 6, 12, 24, 48, 72 and 96 hours. While the forage samples were initially dried at 65°C for 48 hours after the scheduled collection, the concentrates were not pre dried. All samples were milled through a 2mm screen before they were weighed into the bags. Two bags per sample per animal were taken for each incubation time period and anchored into three separate polythene tubings using iron shackles. A sequential withdrawal procedure was followed (Osuji *et al.*, 1993). On removal from the rumen, bags (with contents) were immediately plunged in cold water and quickly washed under running tap water. They were then deep-frozen at about -10°C until the end of all incubation periods. On the washing day all the frozen bags were thawed at room temperature for 3 hours. Then they were washed under running tap water while squeezing between fingers and thumb until the water running through was clear. The bags for zero (0) hour incubation were soaked in tap water at room temperature for one hour and squeezed. All the bags were then dried at 70°C for 48 hours using a forced air laboratory oven (WTB binder type E115 7200 Tuttlingen Germany). DM loss was determined by difference of weights before sample incubation and residue after oven drying (equation vi). The residues were divided into two halves where one

half was ignited for OM determination while the other was subjected to N determination by the Kjeldahl method through standard procedures (AOAC, 1990).

$$\text{DML} = ((W1 - W2)/W1) \times 100 \dots\dots\dots \text{Equation (vi)}.$$

Where DML = DM loss

W1 = weight of sample (DM basis) before incubation

W2 = weight of sample after incubation (residue)

3.4.4 Animal response versus farmers' and laboratory analyses of forages

3.4.4.1 Experimental description of forage preference

3.4.4.1.1 Animals and their management

Four intact crossbred male calves aged between 7 and 8 months and weighing 82.75 ± 0.35 kg (mean \pm s.e.m) were used in the experiments. The animals were mainly of Friesian and Ayrshire exotic breeds crossed with either indigenous TSZ or Boran breeds. These calves had been reared under total confinement since birth until the age of 6 - 7 months when they had occasional outdoor grazing for about a month at the Sokoine University's Experimental Farm, Magadu (Latitude $06^{\circ}5'$ and $07^{\circ}S$ and longitude $37^{\circ}3'$ and $30^{\circ}E$; altitude 500-525 m.a.s.l). They were then transported to the research site 21 days before they were subjected to any experimental work. This allowed the animals to acclimatize to the new site including the feeding conditions and regime. Before transfer, however, all animals were drenched against internal

parasites with a broad-spectrum antihelminthic (Tramazole 10% Albendazole, Univet Ltd, Tullyvin, Cavan, Ireland). Thereafter, they were sprayed fortnightly against external parasites using a commercial acaricide (Stelladone®, Norvatis – Kenya). Each animal was confined to a pen measuring 150 x 175 cm and fed individually. The forages were put in feeding troughs measuring 70 x 40 x 23 cm. Water was supplied *ad libitum* in a separate trough.

The experiment on forage preferences was undertaken for 15 days in which there was seven (7) days of acclimatization period followed by eight days of data collection. During the data collection phase there were two sub-experiments of four days each, involving either offering single or mixtures of two grass species (Table 8 (a and b)). During the acclimatization period and after each of the test-days, animals were fed with a mixture of the four grass species at approximately equal proportions on fresh weight basis. The grasses were *Panicum maximum*, *Panicum trichocladum*, *Pennisetum purpureum* and *Rottboelia cochinchinensis*. All grasses were harvested from communal grazing areas where they were naturally growing (Plates 2 and 3). All the materials were in vegetative stages (before blooming). Collection of forages was done daily from within the 8 km radius from the experimental site. The grasses were harvested in the evening prior to the test-day (using sickles) and stored under shade. The following morning they were chopped to lengths of 15 – 20cm using a *machete*, thoroughly mixed and stored in polypropylene bags prior and during the feeding period (Plate 4). All animals were provided with 1kg of concentrate mixture made of 53% maize bran, 30% sunflower seed meal (SSM), 13% cottonseed meal (CSM), 3% of *Gliricidia sepium* (GSLM) and 1% mineral mix (all on DM basis)

(Table 13). Feeds and water were availed only during the day i.e. from 8.00 a.m. until the end of the data collection for that day (i.e. when all the treatments had been offered) and continued to 7.00 p.m (Plate 5).



Plate 2. Green panic (*Panicum maximum*) in natural environment. This was one of the forages locally favoured and also used in the experiment.



Plate 3. Forage collection for zero grazed cattle in Turiani division. Similar procedures were employed during the feeding trials.



Plate 4. Processing of forages during the experimental feeding. An assistant packs forages in the bag on a day of the experiment.



Plate 5. Experimental animals were closely followed up during the study.

Table 13. Chemical composition of individual ingredients and the concentrate mixture

Ingredient	(g/kgDM)						Energy (MJ ME/kgDM)
	DM	Ash	CP	NDF	Ca	P	
Maize bran	900.9	45.9	98.4	458.4	8.7	1.0	12.40
SSM	943.6	44.0	242.9	575.4	7.3	1.8	12.60
CSM	924.0	69.8	295.0	507.6	10.6	2.3	12.7
GSLM	917.4	99.6	193.4	340.4	3.0	4.1	7.53
Mineral mix ¹	1	100	-	-	175	120	-
Concentrates mixture	912.6	63.3	179.6	491.6	13.6	2.6	12.23

DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fibre

SSM = Sunflower seed meal, CSM = Cotton seed meal,

GSLM = *Gliricidia sepium* leaf meal.

¹Cattlemix Superlick (TAM Abcon Chemicals Ltd Dar es Salaam, Tanzania)

Source: Author's laboratory analysis and other results (2003 - 2004)

NB: The maize bran referred to is actually a mixture of bran, maize polishing and traces of maize flour because all these are not separated in the maize dehulling machines. Usually this by-product is mixed with oil cakes and mineral mix for use as supplements for livestock.

3.4.4.1.2 Single forage presentations

Two kg of chopped green grasses, T1 = *Panicum maximum*; T2 = *Panicum trichocladum*; T3 = *Pennisetum purpureum* and T4 = *Rottboelia cochinchinensis*, were separately measured into a plastic bag of known weight using an electronic digital scale. The test grasses were sorted manually to ensure that a particular grass species was not mixed with other grass species or other plants. The weighed grass species was put in the feeding troughs and an animal was allowed to feed for 15 minutes. Two kg of the test feed were put in another plastic container (control) measuring 60 x 40 x 15 cm in order to measure evaporative weight losses. At the end of every 15 minutes, the amount of grass remaining in the feeding trough was

carefully collected and weighed out; the feeding troughs were then cleaned and a new treatment offered. This continued until all the four species were offered for that day. The order of feeding was altered the following day and consequently in the four days of the trial. Water was available *ad libitum*.

For every order of offer, two independent observers monitored the eating behaviours of animals. These observers were the same throughout the experimental period. Each of them stood quietly from a raised floor bed situated at a distance of approximately one metre from the feeding trough. Using a score sheet and a stopwatch the observer recorded the numbers of prehension bites for the only two animals allocated to him within the total time of observation (15 minutes). This means, therefore, that the four animals were simultaneously tested with the same treatment in random orders (1, 2, 3 and 4) always at the same time of the test day. At the end of each test day (that is when all the forages had been provided as scheduled on the experimental day), every animal was allowed to access freshly prepared mixture of the four grass species and a supplement for the rest of the day. However, the supplement was offered before the rest of other feeds to make sure that all the concentrate mixture was consumed. Each animal was maintained in the same pen and feeding trough throughout the experimental period.

Grab samples from each of the offered forage species were randomly taken and remixed. Two sub-samples of each were packed in paper bags and taken to MSE laboratories for drying and DM content determination. Chemical composition and *in vitro* digestibility of the samples were done as detailed previously.

Calculations:

The amount of herbage intake (HI) was estimated by using equation (vii):

$$HI = (WB_b - WB_a) - (WC_B - WC_a) \dots\dots\dots \text{Equation (vii).}$$

where:

WB_b = weight of plastic bag with forage before feeding

WB_a = weight of plastic bag with forage after feeding

WC_B = weight of control plastic container before feeding

WC_a = weight of control plastic container after feeding

The following calculations were performed for intake rate (IR), bite rate (BR) and average bite mass (ABM) (equation (viii) to equation (x)):

$$IR = \frac{\text{Total DM intake (gDM)}}{\text{Time observed (min)}} \dots\dots\dots \text{Equation (viii)}$$

$$BR = \frac{\text{Total number of bite (bite)}}{\text{Time observed (min)}} \dots\dots\dots \text{Equation (ix)}$$

$$ABM = \frac{\text{Total DM intake (gDM)}}{\text{Total number of bites (bite)}} \dots\dots\dots \text{Equation (x)}$$

3.4.4.1.3 Mixed forage presentations

This experiment followed immediately after the single forage presentation experiment and the conduct was the same (3.4.4.1.2) except that the treatments (M11

– M14) were in a combination of two grass species in equal proportions. Forage combinations were based on local evaluation criteria of availability (abundances) and animal preferences. For example, it had previously been recorded that farmers ranked *P. maximum*, *P. purpureum*, *P. trichocladum* and *R. cochinchinensis* as the most and the least in that order in terms of availability. Similarly, they ranked *P. purpureum*, *P. maximum*, *P. trichocladum* and *R. cochinchinensis* as the most and the least in that order in terms of preference by animals. Thus combinations were made so that at least one of the best ranking species in the availability criterion (*P. maximum* and *P. purpureum*) was combined with a moderately or poorly ranked one (*P. trichocladum* and *R. cochinchinensis*).

Treatments: M11 = *Panicum maximum* + *Panicum trichocladum*

M12 = *Panicum maximum* + *Rottboelia cochinchinensis*

M13 = *Pennisetum purpureum* + *Rottboelia cochinchinensis*

M14 = *Pennisetum purpureum* + *Panicum trichocladum*

All calculations for DMI, intake rate (IR), bite rate (BR) and average bite mass (ABM) in the mixed forage tests followed the same formula used in the single forage presentations (equation (viii) to equation (x)).

3.4.4.2 Determination of intake and growth performance by crossbred calves fed local grass forages

3.4.4.2.1 Animals and their management

Twenty intact crossbred male calves of approximately the same age (8 – 9 months) and weight (average 90.69 kg) were used. Animals were kept in individual pens measuring 150 x 175cm and individually given an *ad libitum* basal diet of common grasses found in the study area. Five animals were allocated to experimental treatment diets (T1 – T4) in a completely randomised design. The grasses were harvested daily using sickles and chopped to lengths of 15 – 20 cm, thoroughly mixed and temporarily stored in polypropylene bags. The forages were offered in portions at 8.00, 11.00, 15.00 and 17.00 hours in order to minimize spill over and contamination. The adaptation and experimental periods lasted for 14 and 90 days respectively. Prior to the experimental period, initial body weights of all animals were measured for three consecutive days prior to giving the morning meals. Subsequent weighing were done monthly for three consecutive days. The average weight of the three weighing was considered to be the weight of the animal in that month. The animals were also treated against external and internal parasites as it was described in section 3.4.4.1.1.

3.4.4.2.2 Treatments and feeding regimes

Two forage species were used to make the four treatments used (T1, T2, T3 and T4). The selection of the forages was based on the dominant use and availability of *P. maximum* in the SPD system and the fact that some forages were not frequently harvested because of inconveniences, labour requirement and availability. On the other hand *P. trichocladum* was chosen as a candidate because at the time of the trial it was relatively easier to find this species than other species i.e. *R. cochinchinensis* and *P. purpureum*. The concentrate mixture used was the same as the one used during the preference study (Table 13). Thus the four treatments were:

T1 = *Panicum maximum* (plus concentrate supplement)

T2 = *Panicum maximum* + *Panicum trichocladum* (in 5:1 ratio)
(plus concentrate supplement)

T3 = *Panicum maximum* (without concentrate supplement)

T4 = *Panicum maximum* + *Panicum trichocladum* (in 5:1 ratio)
(without concentrate supplement)

The supplement was given first before providing the grasses to make sure that no refusal was allowed for this supplement. Water was supplied *ad libitum*. Daily forage materials offered for each animal were recorded separately. Refusals for an individual animal were collected and weighed the following morning prior to the next feeding at 8.00 hours.

3.4.4.2.3 Chemical composition and nutritive value analyses

The samples for offered and refused grass forages were oven dried at 65°C for 48 hours using laboratory oven (WTB binder type E115 7200 Tuttlingen Germany) at MSE. The weighing was done using a laboratory balance (Mettler PM 4600 DeltaRange®, Mettler Instruments GmbH 6300 Giessen, Switzerland) at two decimal places (0.00). All the samples for offer and refusal were respectively bulked and sub samples taken for composition and *in sacco* studies.

3.4.4.2.4 Cost-Benefit analysis

Analysis of costs and benefits were carried out after the growth experiment whereby comparisons were made between bull calves based on *Panicum maximum* alone and those on an alternative practice of combining two grasses (*P. maximum* and *P. trichocladum* at the ratio of 5:1 fresh weight basis), with all treatments given either with or without concentrate supplementation (section 3.4.4.2.2). For treatments in which *P. trichocladum* was included, labour input for harvesting the grasses was costed at Tsh. 750/head/month (This was equivalent to the price of three litres of milk when sold within Lungo or nearby villages). Additional costs of labour for cleaning, weighing and feeding did not vary among treatments. Other variable costs were derived from the cost of concentrate feeds. The cost of the concentrate mixture was based on the daily kgDM intake and was derived from local prices of ingredients used. For the leaf meal ingredient, however, the labour cost for harvesting and processing *Gliricidia sepium* leaf meal was considered to be its market value.

Meanwhile, the fixed cost was assumed to be zero because there were no interest rates for the experimental site or other facilities that were taken into account. The farm gate price for a bull that prevailed in the farming system during the study period was Tsh 630/kgLW. This price was also considered in expressing financial returns assuming the sale of live animals at the end of the experiment.

3.4.5 Secondary information

Secondary data were obtained from the village government offices, divisional office and also from crop and livestock extension workers in the study area. Equally, data accumulated by the ENRECA project on nutritive value of forage species and those from literature at home and institutional libraries (i.e. Sokoine University of Agriculture (SUA, Morogoro) and The Royal Agricultural and Veterinary University (RAVU, Copenhagen)) and world wide web pages were used where appropriate. Weather data were obtained from Mtibwa Sugar Weather Station.

3.5 Data organisation and analysis

3.5.1 General information

The combination of different methods in LK of forages suggested the use of different approaches and instruments in the analysis of data. Thus organisation and analysis of data was undertaken as detailed in the following sub-sections.

3.5.2 Data organisation

For data collected during formal surveys, the initial step was to prepare variables in the form suitable for addressing the research questions and the computer programmes used for the analysis (i.e. the Statistical Package for Social Sciences (SPSS, 1999) or Statistical Analysis System (SAS, 1999). Similarly, data for feeding experiments and laboratory studies were organised first with a spreadsheet package (i.e. MS Excel) prior to using the SAS (1999) for further analysis.

3.5.3 Data analysis

Some PRA tools were instantly used for both information gathering and analysis. However, local understanding and actions gathered through informal surveys and observation techniques entailed the researcher to function as an 'analytical instrument' in order to find logic and context connected to the farmers' activities in forage and livestock management (Vaarst *et al.*, 2002). Nevertheless, the bulk of data were handled through appropriate statistical software and analysed as detailed below.

3.5.3.1 Single household survey data

Statistical measures of central tendency (e.g. mean) and statistical measures of dispersion (range and standard deviation) and percentages were performed especially for cross-sectional survey data and for data of forage samples collected during the longitudinal survey. Statistical packages used were SAS (1999) and SPSS (1998).

3.5.3.2 Farmers' perceptions of forage quality

The GENMOD procedure of SAS (1999) with the logit-link model was adopted in order to analyse farmers' (local) forage quality description with respect to various criteria for quality (response) as itemized in section 3.4.3.2.

In this study the response had four possible outcomes (1 = very poor, 2 = poor, 3 = good, 4 = very good). Independent variables included gender (SEX, male 1; female 2), age (AGERANG, 1= 15 – 30; 2= 31 – 45; 3 = 46 – 60; 4 = > 61), season (SEASON, 1 = dry-cool - June – august; 2 = dry - Sept – Oct; 3 = short rainy – Nov – Jan; 4 = long rainy- Mar - May), heard size (RANGCATT, 1 = ≤ 3; 2 = > 3) and forage grass species (GRASSPEC 1 = *P. purpureum*; 2 = *T. laxum*; 3 = *R. cochinchinensis*; 4 = *P. trichocladum*; 5 = *Cynodon* spp; 6 = *Digitaria* spp and 7 = *P. maximum*). The legume and forb species (LEGFORB were 1= *V. pubescens*; 2 = *I. aquatica*; 3 = *C. africana*; 4 = *M. pruriens*; 5 = *M. atropurpureum*). Variables that were insignificant by Wald statistics (SAS, 1999) were removed from the model so that the final model used in each case was the reduced one. Moreover, the farm (QUESTINN) was specified as a repeated variable. The response levels were sorted in ascending order (i.e. 1,, 4), thus modelling the low ordered level of the rank for the response variable:

$$P_i = \text{prob}(Y = i/X), \text{ for } i = 1, \dots, 4;$$

Where Y is the response variable and X is a predictor variable

The fitted model was:

Logit (p_1) = $\log(p_1/(1-p_1)) = \alpha_1 + \beta * X$ model (iv)

Logit ($p_1 + p_2$) = $\log(p_1 + p_2 / (1 - p_1 - p_2)) = \alpha_2 + \beta * X$ model (v)

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Logit ($p_1 + p_2 \dots p_4$) = $\log(p_1 + p_2 \dots p_4 / (1 - p_1 - p_2 \dots - p_4)) = \alpha_4 + \beta * X$ model (vi)

Variations in the number of responses (N) (both within and between seasons) were encountered because not all farmers responded to all criteria regarding each of the species.

3.5.3.3 Rumen degradability data

The NAWAY procedure (Osuji *et al.*, 1993) was used to calculate degradability constants (a, b, c) for in *sacco* data on the basis of Ørskov and McDonald (1979) model. Effective degradability (p) (Huntington and Givens, 1995) was calculated using equation (xi):

$$p = a + ((b * c) / (c + k)) \dots \dots \dots \text{Equation (xi)}$$

where a, b and c are as described in equation (i)

k = is the rate of passage from the rumen, per hour = 0.02/h

The degradability constants (a; b; c), potential degradability (a+b), effective degradability (p) and degradability at 48 hours were statistically analyzed using the PROC MIXED procedure of SAS (1999) in a CRD with model (vii). The class variables included in the model were the forages (treatments), degradability constants

defined in equation (i), potential degradability (a+b), effective degradability (equation (xi)) (section 2.7.3) and degradability at 48 hours. The animal was included as a random effect.

$$\gamma_{ij} = \mu + \tau_i + e_{ij} \dots\dots\dots \text{model (vii)}$$

where:

γ_{ij} = Observation of the j^{th} animal in i^{th} treatment

μ = Overall mean

τ_i = Effect of i^{th} treatment

e_{ij} = Random error term specific to each individual

3.5.3.4 Determination of forage preferences of crossbred bull calves

The GLM procedures of SAS (1999) were used to analyse the data whereby days and order of offer represented rows and columns respectively of the Latin Square design. The multiple squares approach was followed in the analysis whereby calves represented the squares. This approach was favoured because apart from the interest in the main effects (grass species) and an interest to avoid effects of the day, order or their interaction with the main effect, there was also a need of increasing the efficiency of the model through the repeated square procedure. The general model used for the analysis was written as shown (model (viii)):

$$\gamma_{ijkl} = \mu + \alpha_{i(k)} + \beta_{j(k)} + \delta_k + \tau_l + e_{ijkl} \dots\dots\dots \text{model (viii)}$$

where

$i = 1, \dots, 4; j = 1, \dots, 4; k = 1, \dots, 4; l = 1, \dots, 4.$

γ_{ijkl} = Observation on the i^{th} row (day) associated with the j^{th} column (order) under l^{th} forage species replicated k^{th} times.

μ = Overall mean for the l^{th} forage species associated with the j^{th} order

α_i = Effect of day of offer

β_j = Effect of order of offer

δ_k = Effect of calf

τ_l = Effect of forage species

e_{ijkl} = the residual error term which was assumed to be independent and normally distributed.

The Tukey option of SAS (1999) was used to compare the least square means (LSMeans).

Various multiple regression questions were developed to show relationship between various aspects and response variables associated with forage quality as obtained through feeding and laboratory results. In this case, the relationship between chemical composition and DM intake during the forage preference trial was investigated. Multiple linear regressions were preferred to simple linear regressions as phenomena addressed were products of many variables. The general model was:

$$Y_i = b_0 + b_1x_1 + b_2x_2 + b_t x_t + e_i \dots \dots \dots \text{model (ix)}$$

where

Y_i = the i^{th} observed value of the dependent variable with sample size N

x_1 to x_t = independent variables

b_0 = Intercept

b_1 to b_t are independent variable coefficients

e = error term

$i = 1, 2, 3, \dots, N$

3.5.3.5 Growth and feed conversion ratio

Covariance analysis (Snedecor and Cochran, 1989) was adopted whereby initial live-weight and heart-girth were used to remove the effect of these initial measurements in subsequent body measurements taken. Calculation of intake per body weight was based on initial and mid weights of the calves. DM intake (DMI) was determined by equation (xii). Feed conversion ratio (FCR) was determined by equation (xiii) proposed by Lawrence and Fowler (1997).

$$\text{DMI} = \text{Amount offered (gDM)} - \text{Amount refused (gDM)} \dots\dots \text{Equation (xii)}$$

$$\text{FCR} = \text{Amount consumed (kg/d)} / \text{Liveweight gain (kg/d)} \dots\dots \text{Equation (xiii)}$$

The GLM procedure of SAS (1999) was employed in the analysis of data on growth and feed conversion efficiency. The statistical model (x) was written as:

$$y_{ij} = \mu + \tau_i + b(x_{ij} - \bar{x}) + e_{ij} \dots\dots \text{model (x)}$$

where:

y_{ij} = Observation of the j^{th} animal under i^{th} treatment

μ = Overall mean

τ_i = Effect of treatment

b = Regression coefficient of response variable on initial body weight

x_{ij} = Initial body weight of individual calf

\bar{x} = Mean of initial body weight of all calves in the experiment

e_{ij} = Random error term specific to each individual

3.5.3.6 Feed intake / ingestibility data

The GLM procedure of SAS (1999) was also used to analyse data using model (xi):

$$\gamma_{ij} = \mu + \tau_i + e_{ij} \dots\dots\dots \text{model (xi)}$$

where:

γ_{ij} = Observation of the j^{th} animal in i^{th} treatment

μ = Overall mean

τ_i = Effect of treatment

e_{ij} = Random error term specific to each individual

3.5.3.7 Estimates of cost and benefits

Data on cost and benefits were analysed using model (xii) based on the ANOVA procedure of SAS (1999):

$$\gamma_{ij} = \mu + \tau_i + e_{ij} \dots\dots\dots \text{model (xii)}$$

where:

γ_{ij} = Observation of the j^{th} animal in i^{th} treatment

μ = Overall mean

τ_i = Effect of treatment

e_{ij} = Random error term specific to each individual

3.6 Limitations of the study

1. The 'imprecise nature of local terminology' was encountered, in which, local nomenclature might assign a single name to different forage species (or could put different species in the same group) although these could be differentiated through binomial nomenclature. Similarly, some of the local terminologies that were applied in the use of common forage species simultaneously carried the social, environmental and economic interpretations, which could probably bear different meanings in English or any other language. Nevertheless, necessary precautions to attain and retain the original interpretations were taken during translations from vernacular terms to English. This was achieved through consultations with pasture experts, literature and group discussion.
2. Some of the information collected from farmers relied on memories of respondents and their openness in explaining facts and figures. In many cases, however, farmers do not recall everything or be as faithful as expected. Applications of techniques such as participant observation, the longitudinal design and the researcher's good rapport with villagers were found to be important factors that would lead to obtaining accurate data.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Overview

In the first part of this chapter, an overview of prevailing social life and economic activities in the farming system is given. Subsequently, results of informal and formal surveys on LK of forages, which were the prime subject under study, are dealt with. In the latter part of this chapter, results from empirical assessment of forage preferences and effect of selected forages on animal performance are given together with analytical laboratory results that were obtained.

4.2 Studies on the crop–livestock production system of Turiani division with respect to feeding of local and improved dairy cattle

4.2.1 Household characteristics

Fifty eight percent of the respondents were male and 42% were females (Table 14). Of the total number of respondents (n = 125) 92.8% were married adults, 4% widowed and 3.2% were single. The majority (43.2%) were within the age group of between 31 and 45 years whereas 31% aged between 46 and 60 years. Only 10% of the respondents aged over 60 years. Seventy two percent of the respondents had completed primary school education while 23% had secondary or post-secondary

education. Those who had attended adult education classes and those who had no formal education accounted for a total of 4.8% of all the respondents.

Table 14. Gender, age and education background of respondents

Background		Frequency	Percent
Gender	Male	73	58.4
	Female	52	41.6
	Total	125	100.0
Age of respondent	15 - 30	20	16.0
	31 - 45	54	43.2
	46 - 60	39	31.2
	≥ 61	12	9.6
	Total	125	100.0
Education	Primary	90	72.0
	Secondary	24	19.2
	Tertiary	5	4.0
	Adult education	4	3.2
	None	2	1.6
	Total	125	100.0

This breakdown of respondents and the associated socio-economic indicators depicted a situation common in many rural areas of Tanzania where education was regarded as a throttle to development goals right from the household to national level (Isinika, 2002; URT, 2002; TNW, 2003). Meanwhile, the relatively higher number of male than female respondents encountered indicated the general tendency in rural households of smallholder production systems where cultural and household relations always put the man on the forefront. These tend to give the male some powers and voice over major affairs in the household. Laswai *et al.* (1999) observed a similar trend in pastoral societies of Tanzania and they indicated that in many cases, men were vested with much powers than women in managing resources and other matters of public interest that could have a direct or indirect effect on

household activities. Despite reporting that men were making more decisions, Mullins *et al.* (1996) also noted that rural women were more engaged in production and other household activities than their male counterparts.

4.2.2 Agricultural activities

4.2.2.1. Crop field sizes and associated factors

Fifty two percent of respondents had less than 3.5 ha of land, 28% of respondents owned 3.6 – 6.5 ha while 8% owned more than 11 ha (Table 15 (a)). Crop fields were located at an average distance of 8.57 km away from the owner's home and this indicated that farmers had to travel for some hours to attend their fields. Although there was an average of 2.8 plots per household, further observation indicated that some farmers had other smaller plots (0.10 – 0.41 ha) near the homestead often called '*bustani*' (Swahili) or 'gardens' (English). However, many farmers did not consider these plots to be of any importance when they considered the number of field plots they owned. This distribution of land as well as land fragmentation could have an implication in labour requirement in the management of both crops and livestock particularly because family labour was another major input in the production process. Meanwhile, 88% of all respondents expressed a need for more land (Table 15 (b)).

Table 15 (a). Responses to field size by different age groups in Turiani division

Field size (ha)*		Age of respondent				Total
		15 - 30	31 - 45	46 - 60	≥ 61	
≤ 0.9	n	5	9	2	0	16
	% of total	4.0	7.2	1.6	0	12.8
1.0 - 3.5	n	9	22	14	4	49
	% of total	7.2	17.6	11.2	3.2	39.2
3.6 - 6.5	n	4	12	14	5	35
	% of total	3.2	9.6	11.2	4.0	28.0
6.6 - 10.5	n	1	6	6	2	15
	% of total	0.8	4.8	4.8	1.6	12.0
10.6 - 14.5	n	0	0	0	1	1
	% of total	0	0	0	0.8	0.8
≥14.6	n	1	5	3	0	9
	% of total	0.8	4.0	2.4	0	7.2
Total	n	20	54	39	12	125
	% of total	16.0	43.2	31.2	9.6	100.0

* Plot size: Mean 4.73 (ha) SD =5.32 Maximum 34.02 Minimum 0.20

$\chi^2 = 21.64$, df 15, P = 0.117; SD = standard deviation; (n= number of respondents)

Number of plots: Mean 2.81, SD= 1.47; Maximum 9.00 Minimum 1

Distance from home (Km): Mean 8.57 Maximum 50.0 Minimum 0.10

Table 15 (b) Requirement of additional land for cropping in Turiani division

Requirement		Frequency	Percent
Desire for cropping land	Yes	110	88.0
	No	15	12.0
	Total	125	100.0

Those who indicated that they did not need more land were mostly the old ones whose energy and health status inclined them to stick to the field plots they currently owned. However, there was no significant ($P > 0.01$) difference in land ownership among different age groups.

The quest for more land observed in the SPD could be explained not only by the large household size (6.84 ± 0.25 , mean \pm std error) but also by the human population

growth rate that is estimated at 2.6% annually (TNW, 2003). Population increases in the SPD could be due to immigration either for permanent settlement or for seasonal employment opportunities in Mtibwa Sugar Estates (MSE) particularly in sugar plantations and factory. It is worth noting also that Turiani division has plenty of land with good potential for agriculture due to fertile soils (URT, 2002) and good weather (Figure 9 and Figure 10) such that other people tend to move in from other areas of the country for settlement.

On the other hand, economic reforms in Tanzania that began in the 1990s had led to the privatisation of the MSE. The owner has, therefore, embarked on the rehabilitation of the sugar processing plants and opening up more land for new sugarcane plantations. These socio-economic changes and the demographic factors discussed above are likely to lead to continuous fragmentation of household fields (in the long run) and to changes in land and other resource utilization patterns. For example, these factors may affect ownership and utilization of rangelands that were owned communally prior to the reforms. Meanwhile, the results on size of plots and the felt needs of more farming land are comparable to that observed in other parts of the country (Maruo, 2002; Mkamilo, 2004) and also other parts of Africa, Latin America and South Asia (de Leeuw *et al.*, 1999; Devendra and Thomas, 2001; Phiri *et al.*, 2004).

4.2.2.2 The livestock component

Livestock statistics indicated that chicken were predominant among the livestock species kept where the average numbers per household for crossbred cattle, goats and chicken was 2.24, 2.84 and 14.11 respectively (N = 125) (Figure 12). Generally, the responsibility of taking care of the small and large ruminants was vested to all members of the households. However, the management of chicken was mostly the responsibility of female adults and children. In many households the birds were kept under free-range system with varying housing structures and minimal or no feed supplements. However, it was observed that there were farmers' groups for chicken production in Lungo and Kidudwe villages where activities on the management of the birds such as flock recording and disease control were undertaken. This was encouraged by a project on the improvement of the productivity of scavenging chicken that had been taking place in the study area (Minga *et al.*, 2001). The division of labour among different gender categories observed in the SPD was common in many rural settings and was a traditional way for the efficiency of labour and LK applications (ole Lengisugi, 1995; Maruo, 2002).

The practice of keeping several types of livestock that was observed in the study area was typical of most smallholder holdings in developing countries where a farmer keeps different types of livestock species mainly for socio-economic and socio-cultural reasons (Bebe *et al.*, 2003a). These reasons range from wishes to maximize returns from smallholdings and avoidance of risks upon poor performance of some of the livestock species kept (Udo, 1997), to social needs of specific livestock types in

cultural/religious ceremonies, for payment of dowry or bride price (Moll, 2004). Meanwhile, the average herd and flock sizes for cattle and chicken in the SPD were within ranges reported elsewhere for smallholder production systems (Udo, 1997).

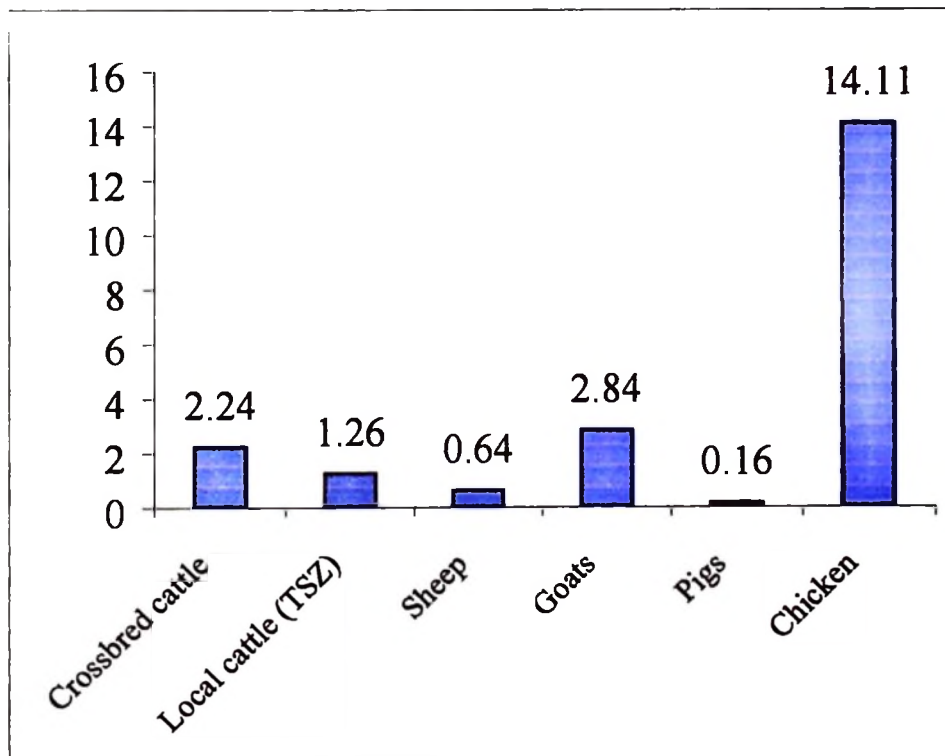


Figure 12. Average of number of livestock per household in Turiani division (Calculations based on a sample of 125 households surveyed)

4.2.2.3 Cattle husbandry in Turiani division

4.2.2.3.1 Regional origins of cattle keepers in the study area

Table 16 depicts the respondents' residence category, origin and average time of cattle keepers living in the study area. Seventy eight percent of respondents had moved to the study area and the rest were born therein. More than half (69.4%) of

those who had come into the division from other places in the country (other than Morogoro region) had settled in the area for more than ten years. Over the years, the blend of own intuitions, local traditions and prevailing climatic and socio-economic conditions were likely to have influenced farmers' practices in livestock husbandry in general and in dairy cattle and feed resource management in particular.

Table 16. Residence, origin and time since moving in Turiani division for various respondents

	Frequency	Percent
Residence category		
Born	27	21.6
Moved	98	78.4
Total	125	100.0
Origin before coming to Turiani		
Morogoro region	30	30.6
Other regions	68	69.4
Total	98	100.0
Time since moving in (years)		
≤ 5	11	11.2
6-10	21	21.4
≥ 11	66	67.3
Total	98	100.0

4.2.2.3.2 Herd composition

The dairy herd composition in the SPD had a good number of cows (52%; n = 280) with heifers and bulls being 12% and 7% respectively (Figure 13). The bulls accounted for were only those aged over one year and above, regardless of whether the animals were purposely selected for breeding or not. However, the small number of bulls found in the study area was a reflection of farmers' unwillingness to keep animals that could not generate daily or short-term incomes. In most cases, male

calves were likely to be sold earlier with most of them ending up in slaughterhouses. It is worth noting, therefore, that farmers were sensitive to feed requirements and other inputs that are necessary in the management of milking cows that were obviously regarded as direct producers. On the other hand, draught animal power that could utilize oxen or other classes of livestock was not common in the SPD as it was in other farming systems where animal traction was valued (Maiseli and Ulotu, 1995; Bebe *et al.*, 2003a).

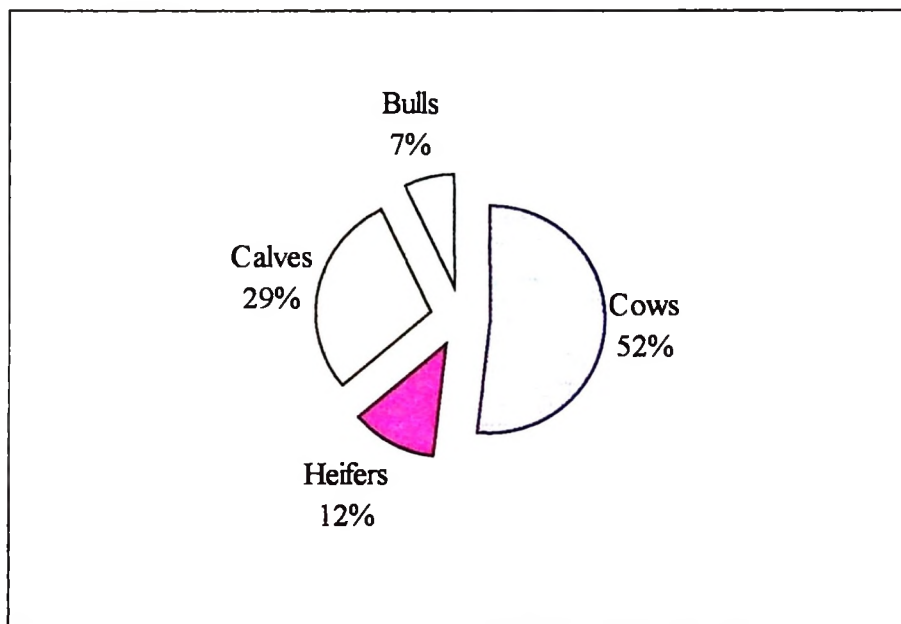


Figure 13. The general structure of the dairy herd in Turiani division depicting percentage of bulls, calves, cows and heifers (N = 280)

NB: Bulls include males aged over one year, regardless of whether they had been selected for breeding or not.

Calves include all males and females less than one year.

Cows include females which had calved one or more times.

Heifers include females over one year but had not calved at all.

The strategy of keeping few or no bulls in smallholder farms has been observed elsewhere in the tropics (de Leeuw *et al.*, 1999). Nevertheless, the small number of heifers raised an alarm to a strategic breeding plan by individual farmers and other stakeholders (e.g. farmer organisations, local or central government) and for sources of replacement heifers when the current producing cows are due for substitution (Kyomo, 2001). This could have an important impact both on the present and future performance of the small-scale dairy sector in the SPD.

4.2.3 Farmer experimentation

It was observed that 39% and 35% (N = 125) respectively had done experimentation in crop and livestock related activities (Table 17). Although there was less experimentation in livestock husbandry than in crop production, the difference was not significant ($P > 0.05$).

Table 17. Farmer experimentation in crop and livestock husbandry

	Experimentation in crops		Experimentation in livestock	
	Frequency	Percent	Frequency	Percent
Yes	49	39.2*	44	35.2*
No	76	60.8	81	64.8
Total	125	100.0	125	100.0

*Paired t- test: Df = 124; SEM = 0.05; significance level = 0.437.

Generally, farmers did some experimentation in order to test some of the new technologies and to modify some of the known technologies to suit particular farm conditions (Kajembe *et al.*, 2000a). Some farmers would initiate some trials so as to find out what would happen if they did something that they had not done before out

of curiosity. Sometimes, this was either what they had heard or what they saw others doing. The general practices and approach to experimentation found in the SPD were observed in other mixed systems in Iringa region, Tanzania (Ravnborg, 1996) and elsewhere (Kajembe *et al.*, 2000a; Quoroz, 1996).

Experiments in crop production varied from field-testing of new or unfamiliar seed types to post harvest testing of the efficacy of some herbs on the stored crop produce. However, most of these (41%, N = 49) involved planting methods such as row against the traditional 'haphazard' planting (Table 18). Owusu (1993) reported similar observations in Ghana where farmers conducted experiments that included field fertilization with leaves from multipurpose trees and on plant spacing.

Experimentation in animal husbandry was mostly related to feeding (77% N = 44) with relatively few (4.5%) experiments in treatment of diseases (Table 18). In these feeding experiments, some farmers were curious to see whether animals would accept certain kinds of unfamiliar types of forage / supplements. In some instances, however, farmers reported that they would mix different types of forage grasses and observe which ones were readily picked by stall fed animals. In other cases, they reported to use crop residues and industrial by-products in cattle feeding whereby molasses-water solution was sprinkled on crop residues in order to improve palatability. Molasses could be easily obtained from Mtibwa sugar factory but there was very little practice in using the water-soluble carbohydrate.

Although observation indicated that farmer experimentations had promising results, those trials that depended on regular purchases of inputs were not sustained. The

Although observation indicated that farmer experimentations had promising results, those trials that depended on regular purchases of inputs were not sustained. The subsistence scale of operations aggravated by little capital investment and poor infrastructural set-up could explain this limitation. Nevertheless, farmer experimentation was an indication of farmers' effort in managing their resources to cope with variability and complexity of production systems (Quoroz, 1996). Since the types of experiments conducted by farmers were through their own initiatives it was obvious that many of the experiments were done to suit specific circumstances

Table 18. Experiments conducted by farmers in crop and livestock husbandry

Type of experimentation (crops)	Count	Percent
Seed test	18	36.7
Planting methods (spacing etc)	20	40.8
Post harvest	2	4.1
Horticulture	4	8.2
Fertilizer trials	5	10.2
Total	49	100.0
Type of experimentation livestock		
Feeding trials	34	77.3
Treatment of diseases	2	4.5
Breeding (upgrading)	8	16.3
Total	44	100.0

Actually, it was through these local initiatives that applications of LK to solve instant and subsequent problems could emerge and be developed (Kajembe et al., 2000a).

experimentation. Quoroz (1996) noted that this was a common phenomenon in many situations.

Generally, experiments conducted by farmers were those that were unlikely to involve high risks. That was probably why experiments geared towards direct production goals (i.e. those on yields from new seeds or on feeding of livestock for direct outputs) outnumbered risky experiments involving the whole experimental unit (such as those on treatment of animal diseases). The manner and attitudes of farmers in handling farm situations whereby many farmers would not venture into risky investments could explain these observations. This was similar to what was reported elsewhere (McDermott *et al.*, 1999; Romney *et al.*, 2003) that smallholder farmers were very keen in practising and selecting technologies that minimize risks in production.

4.3 Local knowledge of forage quality

4.3.1 Interpretation of language and terminologies used in forage quality assessment in smallholder livestock systems of Turiani division

4.3.1.1 General terms in decisions making

Terms translated as '*suitable*', '*good*' and '*bad*' were key verbal expressions that were used by farmers to infer to the quality status of the locally available feeds. These terms were deduced from daily or frequent use and farmers' perceptions of

quality of green grass forages and other feeds used for the dairy herd. The application of the terms and consequent actions on the use of feed resources depended mainly on three things summarised in Figure 14. These are farmer's **general judgement** of (forage) situations, any **alternative(s)** at his or her disposal at the time of the judgement and consequent **action(s)** taken sooner or later. At the judgement level, which can also be termed as the general assessment stage, the farmer's decision to use particular forages depended on whether the latter met the general criteria of quality. These decisions are based on farmers' objectives in livestock production or aims of keeping the dairy cattle in particular, that is (1) quantity of milk produced (2) quality of milk produced and (3) status of the individual animal or herd including health and/or weight gain and (4) farmers' convenience in harvesting or feeding the animals based on the visible (physical) and innate (chemical) characteristics of the forages.

Immediately after the general assessment on quality of forages, the farmer is always confronted by the decision of how to deal with the forages. In respect to good forages, the farmer could directly use the available resources (action) once he/she had made his/her own judgement. However, the decision on forages that were not good was made with a pre-condition of presence or absence of other alternatives. Decisions about the use of forages in the SPD farming system represented some of the varied choices that farmers ought to make about the use of grass forages and other feed resources available on the farm.

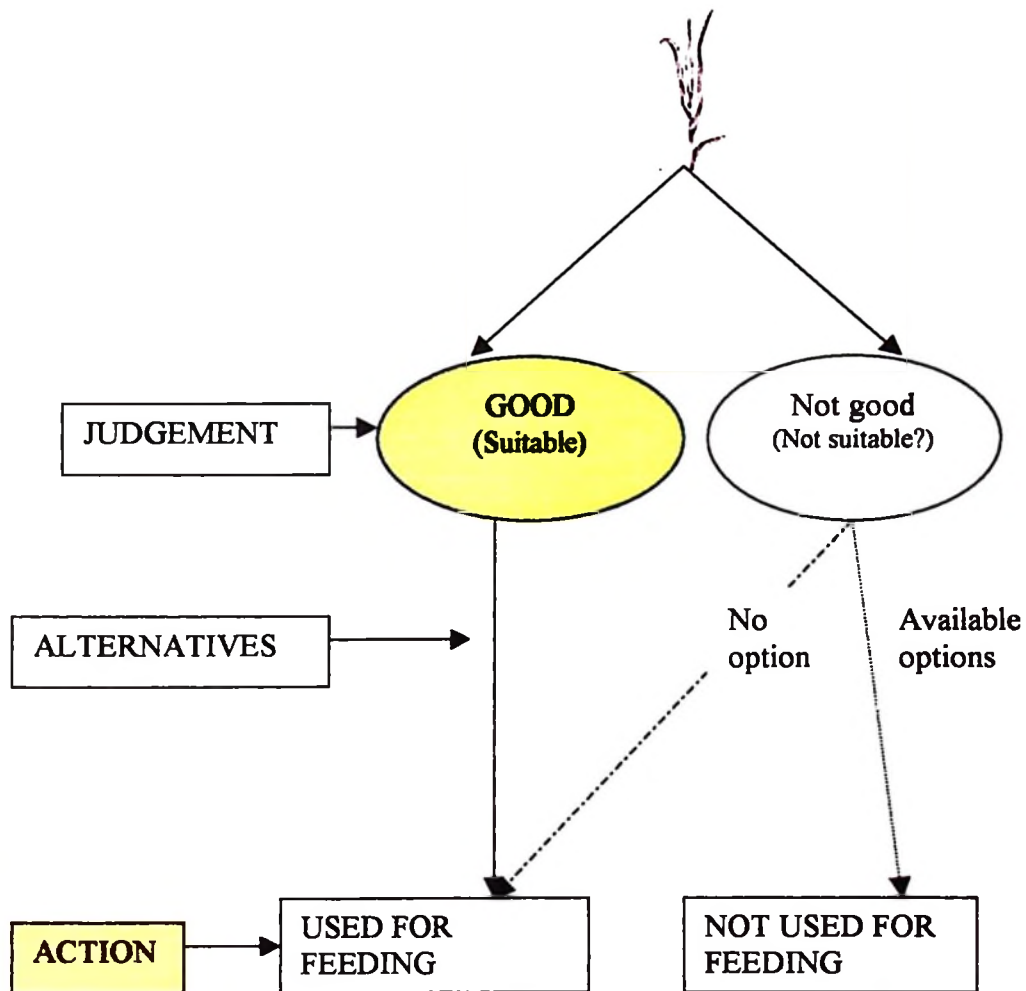


Figure 14. Judgement and actions surrounding the use of forages in smallholder farms

These decisions were also taken amidst other choices and actions related to crop production and other off-farm activities. As Douthwaite *et al.* (2003) put it smallholder farmers always conduct a variety of activities with multi-objective functions and expectations.

4.3.1.2 Terminology in forage quality description

The summary of local terms and circumstances surrounding the use of these terms and expressions are also shown in Table 19. Although experience indicated that direct translation of the local terms to English or any other language was likely to complicate or distort original meanings, effort had to be made during translation so as to retain farmers' intentions and consequent meanings as it could be expressed in the local term on daily use of feed resources. However, the complexity in the language and terminology used reflected the complexity of LK in the assessment of natural resources. Therefore, the work on quality perception among the smallholder farmers in the SPD farming system revealed not only the essence of confirmation of the terms but also the burly view that local terminology holds in addressing resources available in the myriad options influenced by biodiversity, culture and opportunities. This was not surprising because LK is characteristically implicit and contextual (Chambers *et al.*, 1989; Sinclair and Walker, 1998). However, this nature of LK does not reduce its relevance in its application particularly when the former is systematically done within the same or in a similar production system(s) where it has been developed and used.

Table 19. Description and implications of terms for forage qualities in Turiani division

Local term (Kiswahili)	English synonym	Further explanation and practical implications
(1) <i>-faa</i> (verb, adjective) e.g. (a) <i>Malisho haya yanafaa</i>	<i>benefit, be convenient, suit, suitable, be of use</i> e.g. (a) <i>These forages are suitable</i>	The use of ' <i>suitable</i> ' forages had different interpretations depending on prevailing circumstances in a farm: (a) Yes, the farmer is contented with the forages and uses them (b) Yes, the farmer uses the forage but could resort to other types if there is such an opportunity
(2) <i>-fai</i> (the opposite of 1; <i>-faa</i>) (verb, adjective) e.g. (a) <i>Malisho haya hayafai</i>	<i>unsuitable, not beneficial, not useful, not convenient</i> e.g. (a) <i>These forages are not suitable</i>	The use of the forages that are 'not suitable' also had different interpretations on practical basis: (a) Yes, forages are not suitable but one could or could not use them depending on circumstances [(refer practical implication 1b above)].
(b) <i>Malisho haya</i>	(b) These forages are ...	(b) These forages are ' <i>not suitable but</i> ' or are ' <i>not suitable at all</i> '
(i) ' <i>Hayafai kiasi au hayafai ila ..</i> '	(i) ' <i>not suitable but</i> '	(i) ' <i>not suitable but</i> ' – implies some tolerance to using 'unsuitable' feed material. This may be due to e.g. absence of the 'best' option
(ii) ' <i>Hayafai kabisa</i> '	(ii) ' <i>not suitable at all</i>	(ii) ' <i>not suitable at all</i> and (so) That is 'this type is not give any second thought....' <i>should be rejected</i> '.

Table 19 continued.

Local term (Kiswahili)	English synonym	Further explanation and practical implications
(3) -zuri (adjective) e. g. <i>Malisho haya ni mazuri</i>	'good' e.g. <i>These forages are good</i>	The use of 'good' forages was also interpreted differently: The farmer concludes that forage (quality) is sufficient to guarantee his / her objective. It could be that forages are good for milk let down, increasing milk yield, inducing heat etc. However, this explanation goes at different levels such as:
(i) <i>mazuri sana</i>	(i) 'Very good'	(i) The forages are valued in such a way that in order to make sure that a farmer (and so the cow or any other class of cattle kept) cannot do without them something has to be done. For example, if a farmer was working in another field (away from home where cattle are zero grazed) and found such species labelled 'very good' he/she could do whatever possible to cut and carry (say one or more kg of) such species. In other words, whenever possible such forage materials must be fed to the animals.
(ii) <i>Mazuri kiasi</i>	(ii) 'Good', 'fairly good'	(ii) 'Good', 'fairly good' but'. Here it implies that farmer agrees that the material is 'good' to feed, but if there is another alternative (e.g. time for collection, available in the field / rangeland etc.) then he/she could resort to something else. This could also be explained as 1 (b) above.
(4) -baya e.g. <i>Malisho ni mabaya</i>	<i>bad, not good</i> Forages are not good	The 'Not good' is further categorised as
(i) 'Mabaya kiasi' na	(i) 'not so bad but... ..'	(i) 'not so bad but'. Yes, not good but ... can still be of use and
(ii) <i>mabaya sana</i>	(ii) 'very bad'	(ii) 'very bad' and so could be rejected outright.

It is worth stressing that in order to arrive at useful and meaningful information emanating from descriptive utilities of LK it was thought important to facilitate free dialogue among farmers during group discussions. This also entailed careful interpretation of the meaning of local nomenclature and basis of quality descriptions through available literature (Terry and Michieka, 1987; Legère, 2003; Kamusi, 2004). An extended stay in villages also created rapport with farmers on practical applications of the terminologies. The usefulness of the approach and applications of local terminologies have been emphasized elsewhere where King (2000) found local terminologies and folk taxonomy to be entry points into understanding how people classify and value resources and the environment. However, Sinclair and Walker (1998) proposed that it was important to interpret local terminologies carefully so that at the end of the day it could be possible to seek for consistency (or otherwise) of the results. Similarly, Douthwaite *et al.* (2003) reported further advantages of careful interpretations through a case whereby critical analysis of LK led to ideas beyond the original facts and plans for some technological interventions in smallholder farming systems in Uganda.

4.3.2 Identification and practical use of feed resources

The use of the Tanzania's national language (Kiswahili) and flexibility imposed in the use of local terminology allowed farmers to contribute ideas in the identification of the common forages they used. This identification based on local terminology was also a reflection of farmers' understanding of the available resources in general and the different strategies in using and managing the various forages. The extent in the

use of different types of forages varied across locations as indicated in Table 20. For example, *R. cochinchinensis* and *Brachiaria* spp were commonly used in the Kidudwe and Lungo villages. Meanwhile, most of the trees and shrubs used for feeding were exotic to the study area except *F. virosa*. The latter was commonly used in lower altitude areas of Lungo and Kidudwe villages.

Table 20. Forage grasses and legumes frequently used for zero grazed cattle in Turiani Villages

Class	Local name*	Binomial nomenclature	Village				
			Manyinga	Kichangani	Lungo	Kidudwe	
Grass	Magugu (Ngugu)	<i>Pennisetum purpureum</i>	√√√	√√√√	√	√	
	Masinde (Kalahinde)	<i>Panicum maximum</i>	√√√	√√√	√√√	√√√	
	Mbayaya	<i>Rotboellia cochinchinensis</i>	√√	√√	√√√	√√√	
	Gwatamala	<i>Trypsacum laxum</i>	√√	√√	√	√	
	Mbudu	<i>Cynodon</i> spp	√	√	√	√	
	Sangari	<i>Digitaria</i> spp	√	√√√	√	√	
	Ukoka	<i>Panicum trichocladum</i>	√	√√	√√	√√√	
	Mshengeri	<i>Brachiaria</i> spp	-	-	√	√	
	Legumes and forbs	Njegere pori	<i>Vigna pubescens</i>	√√√	√√√	√√	√√
		Kunde pori	<i>Macroptilium atropurpureum</i>	√√√	√√√	√√	√√
		Upupu	<i>Mucuna pruriens</i>	-	-	√	√
Tembele pori		<i>Ipomea aquatica</i>	√√√	√√√	√√	√√	
Kongo (Kongwe-kongwe)		<i>Commelina africana</i>	√	√√	√√	√√	

* Based on Kiswahili and/or some vernacular languages spoken in the study area.

Key: √√√ = Present, recognized and used by most of the respondents

√√ = Present, recognized and used by some of the respondents

√ = Present, recognized and used by very few people

- = Not mentioned

On the other hand, forbs such as *I. aquatica* were commonly used in Kichangani and Manyinga villages. Crop residues were infrequently used in all areas except maize stover and *V. unguiculata* leaves that were normally fed in green forms shortly after crop harvests. These variations in daily use of different forages may originate from variations in micro- and macro environments in which different farmers operate. In Mhonda and Sungaji wards, for example, farmers lived in proximity to permanent rivers and fertile flood plains, unlike most of the farmers in Mtibwa ward. Due to these topographic differences, therefore, the farmers in Manyinga and Kichangani villages infrequently used annual grasses because perennial species (e.g. *P. maximum*) were abundant almost throughout the year.

The common trees/shrubs and crop residues found in the SPD of Turiani division are shown in Table 21. It was observed that though crop residues were abundant many farmers did not use them frequently. This could be due to the relatively stable supply of green grasses, legumes and forbs from various sources. The relative utilization of various forage materials in Turiani division is shown in Figure 15.

4.3.3 Complexity in local nomenclature

Complexities of terms were also evident in the study villages in naming of some of the forage species whereby a single local name could apply for one or more forage type or different species with reference to binomial nomenclature. For example, the

term 'Nyasi' was used as a collective term to refer to any plant of the family Graminae (cf. green or dry grass (hay) regardless of species). Similarly, 'Nyasi' as used by some farmers included grass types whose binomial nomenclature led to classifications into *Cynodon* and *Digitaria* spp.

Table 21. Some trees/shrubs and crop residues used in Turiani division

Class	Local name*	Binomial nomenclature	Village			
			Manyinga	Kichangani	Lungo	Kidudwe
Trees / shrubs	Lukina	<i>Leucaena leucocephala</i>	√	√	-	-
	Mzabibu pori	<i>Morus alba</i>	√√	√	√√	√√
	Mjohoro	<i>Senna siamea</i>	√	√	√√	√√
	Sesbania	<i>Sesbania sesban</i>	-	√√	√√	√√
	Mkwambe-kwambe	<i>Fluogea virosa</i>	-	-	√	√
	Gliricidia	<i>Gliricidia sepium</i>	√	√	√√	√√
Crop residues	Miwa (Majani ya miwa)	<i>Saccharum officinarum</i> (Sugarcane tops)	-	-	√	√
	Mabua ya mahindi	<i>Zea mays</i> (Maize stover)	√	√	√	√
	Tembele (Majani ya viazi)	<i>Ipomea batatas</i> (Sweet potato vines)	-	√√	-	-
	Kunde za kula (Majani)	<i>Vigna unguiculata</i> (Leaves)	√√	√√	√√	√√
	Migomba (Mabaki)	<i>Musa parasidiaca</i> , <i>Musa sapientum</i> (banana leaves/ pseudostems)	-	-	-	√

* Based on Kiswahili and/or some vernacular languages spoken in the study area.

Key: √√√ = Present, recognized and used by most of the respondents

√√ = Present, recognized and used by some of the respondents

√ = Present, recognized and used by very few people

- = Not mentioned

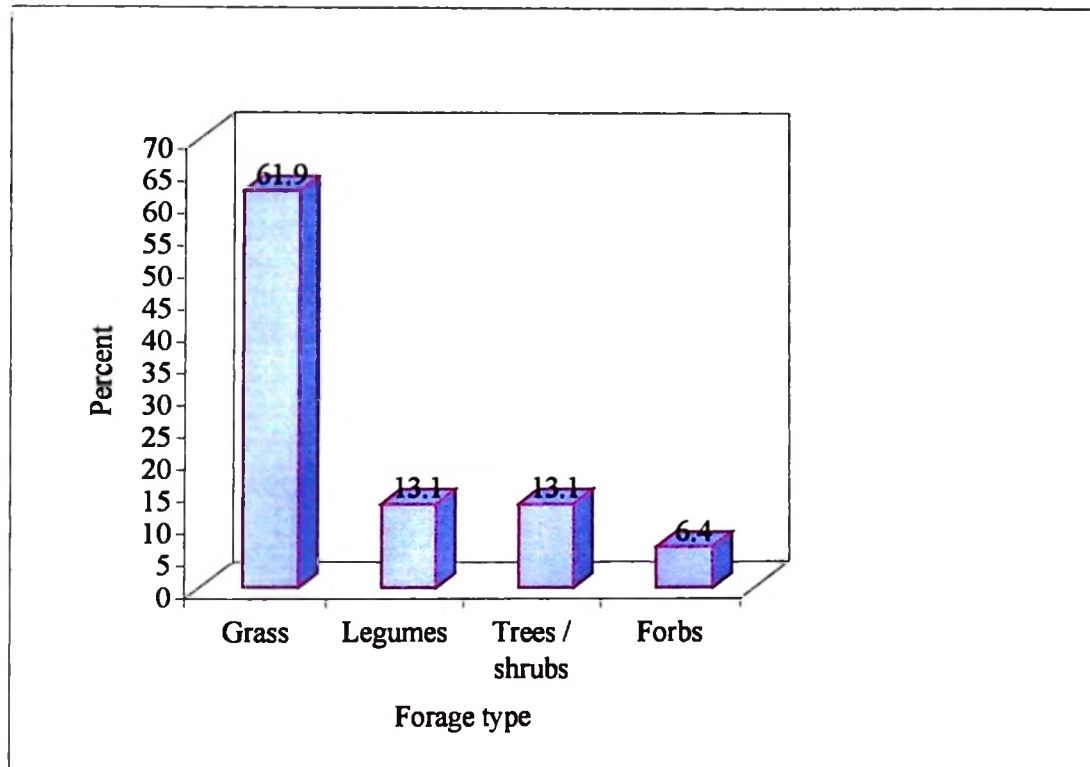


Figure 15. Utilization of different forages in smallholder farms in Turiani division

On the other hand, local nomenclature ‘*Mbudu*’ and ‘*Sangari*’ were used by some farmers to refer to different grass species although to other farmers they were synonymous. However, further observation indicated that ‘*Mbudu*’ was a local name for the *Cynodon* spp (mainly *Cynodon dactylon* and *Cynodon plectostachyus*) whereby ‘*Sangari*’ referred to *Digitaria* spp. This encounter in nomenclature with local terms having different names or interpretations either locally or by external agents led to what Sinclair and Walker (1998) described as ‘*the imprecise nature of the local terminologies*’. Local terminologies, of course, ought to be approached cautiously by anybody who is interested in learning something in a new environment, for example, about resource utilization in smallholder settings. Nevertheless, the general information obtained after scrutiny and confirmation of the precise meaning

of the words used by farmers is extremely important. Legère (2003) had equally challenging experiences when he obtained plant names that had linguistic correspondence or near correspondence among the Kiswahili speaking communities in Zanzibar that were later found to be botanically different. Furthermore, studies among pastoralists and agro-pastoralists in different areas of Africa (Niamir, 1990) underscored the detailed knowledge of micro-variation in vegetation emanating from complexity and diversity of the environment and patterns and priorities of local uses.

4.3.4 Local practices and climatic conditions

Although the grass and legume forages were harvested and fed in mixtures, it was very common to find *P. purpureum* and *P. maximum* dominating any load of grasses harvested. In some situations, these were the only grass species used as basal diets for zero grazed animals. Farmers' inclination to frequent use of relatively fewer species available for feeding was attributed mainly to availability in terms of abundance at a single point or place of harvest; seasonal and spatial distribution (Figure 16).

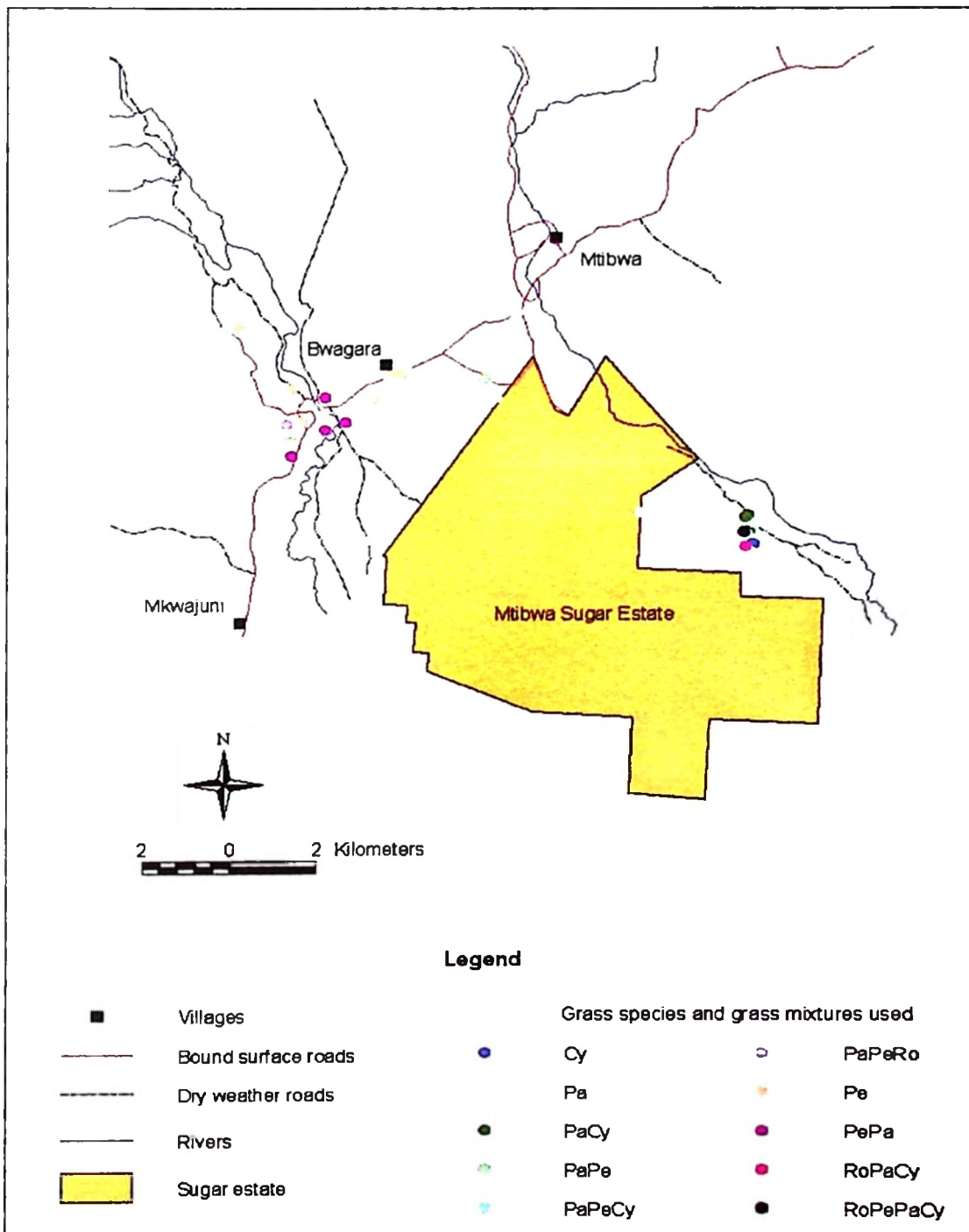


Figure 16. Dominance and use of grass species by GPS sample households

Key:
 Pa = *P. maximum* Cy = *Cynodon* spp Pe = *Pennisetum purpureum*
 Ro = *R. cochinchinensis* PaCy = *P. maximum-Cynodon* mixture
 PaPe = *P. maximum-Pennisetum* mixture PaPeCy = *P. maximum-Pennisetum-Cynodon* mixture
 PaPeRo = *P. maximum-Pennisetum-Rotboellia* mixture
 RoPaCy = *Rotboellia-Panicum-Cynodon* mixture
 RoPePaCy = *Rotboellia-Pennisetum-P. maximum-Cynodon* mixture

The habit observed for frequently harvesting *P. purpureum* and *P. maximum* was also associated with convenience that could directly be translated into labour requirements. Generally, both farmers and hired labourers would find it more convenient to harvest grasses that were 'bulky' and 'more conspicuous' (such as *P. maximum*) than 'the less conspicuous' grasses (i.e. *Cynodon* spp). This was because it was felt easier to harvest and attain the desired quantities of the former species than the latter. The time saved for easy and quick harvesting of 'the more convenient species' would thus be devoted to other farm or off farm activities. Earlier observations had indicated that for many farmers it was necessary to walk to distant fields where food and/ or cash crops are grown (section 4.2.2.1). More over, it was also due to felt and/or observed animal performance in a short or long term of forage utilization (section 4.4). Environmental and natural factors that contributed to variations in availability of different forage species also included topography and drainage systems such that farmers in the vicinity of valley bottoms and rivers considered *P. purpureum* to be readily available (Figure 16 and Figure 1). However, the absence of a very distinctive moisture deficient season and natural drainage systems rendered many types of forages to remain green for the most part of the year. The seasonal calendar on availability of forages that was drawn during a PRA session revealed that there was a reliable supply of different pasture species in the study area (Figure 17). Nevertheless, the feed resource base could slightly vary from one village to another depending on climate, soils or intensity of cattle keeping activities in a given locality (Lekule and Sarwatt, 1996; Utiger *et al.*, 2003).

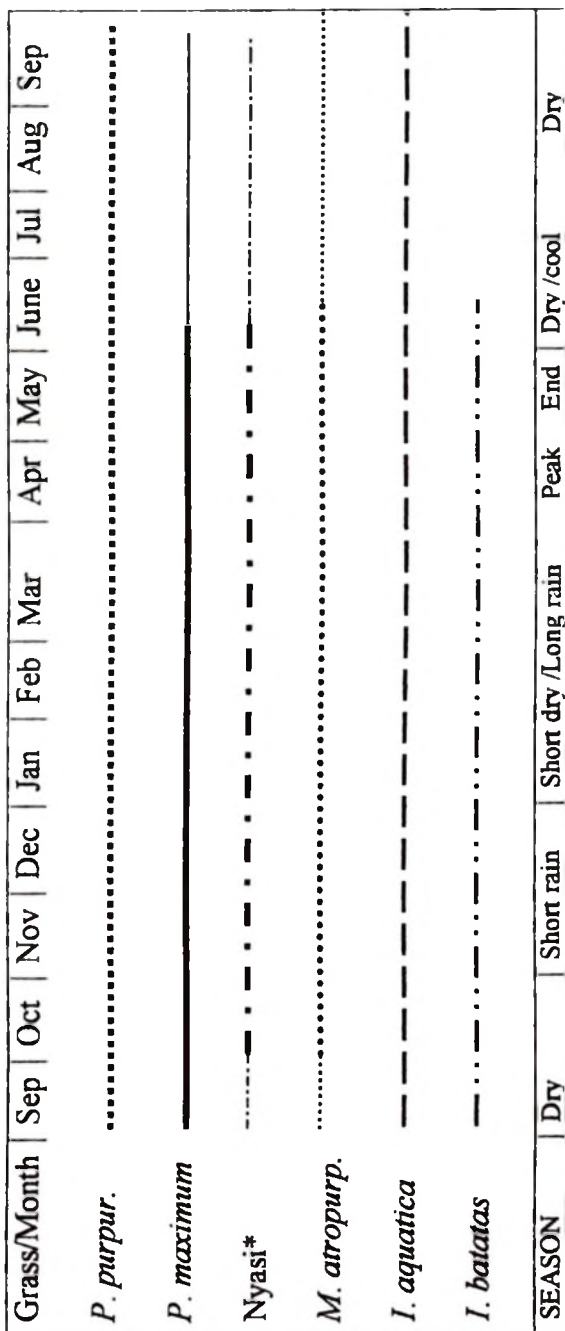


Figure 17. Seasonal calendar: Availability of forages for zero grazed cattle in Kichangani village

Key: Heavy lines indicate abundant forages available in respective months
 Lighter lines (especially in the dry season) indicate shortages in supply
 * Local terminology used to designate *Cynodon* spp or *Digitaria* spp

4.3.5 Knowledge and practice in the utilization of local forages species

The choice and use of *suitable* or *good* forages so as to realize the intended production objectives were obviously convincing. However, the use of forages that are known by the farmer not to be suitable [i.e. '*not suitable but ...*' or '*fairly good ...*' (see Table 19 and Figure 14)] may instantly send a surprising message to any stranger in the farming system. But as it was pointed out before, forage species were fed based on available alternatives or otherwise. This means, therefore, that the use of forages that were considered un-suitable was done because the forages of first choice were not readily available. This is a common phenomenon in many livestock production systems in the tropics where, during the dry season, for example, most of the forages are either not available or have poor nutritional quality (Ogle, 1990; Zemmeling *et al.*, 2003). On the other hand, the use of un-suitable forages was a momentary issue due to other pressing factors to the farmer (such that the best alternative forages were not at hand only briefly). For example, at a time when a farmer is constrained with labour or the feed resources of the first choice, he/she could opt to give the animals the forages, which in his or her own view are not very good. Under practical zero grazing situations where forages are harvested every day, grass forages given to cattle at one time in the morning would be the ones considered "not very good" just because the "good" material would be brought in later in the day. In this case, therefore, farmers' feeding practices would have deviated from what they acknowledged to know to be beneficial. Such choices and decisions as those encountered in the SPD resembled the multi-criteria decisions taken by smallholder farmers in other developing countries (Moll, 2004).

In other situations, farmers reported that some forages were *good* or *bad* without giving satisfactory reasons as to why was the case. On one hand, this may be due to the fact that what a farmer happened to know may not be from his or her own experiences but probably due to what one may have heard from others. On the other hand, it may be true that a farmer judged the forages in whatever way because of his/her own experiences, but did not know exactly the reasons or basis of such observations. It was probably under these circumstances that Ravnborg (1996) argued that farmers would know problems in general without specifying reasons or causes of the problems they encountered. Farmers' acknowledgement of the suitability of forage species led to some deliberate effort to ensure steady availability for some of these species. This was evident in *in situ* and other management practices for native forages whereby 73% of all those who had some conservation efforts used to establish some suitable grass species (n=78) (Table 22).

Table 22. Efforts in maintaining continued availability of good quality forage species in Turiani division

Effort for forage availability		Frequency	Percent
Any effort made	Yes	78	62.4
	No	47	37.6
	Total	125	100.0
Specific type of effort			
Establishing some species		57	73.1
Fetch them where they are available		16	20.5
Careful in harvesting		4	5.1
Dry season conservation		1	1.3
Total		78	100.0

Generally, the overall number of farmers who carefully harvested and those who conserved the materials for dry season feeding was very small, accounting to 3.2% and 0.8% respectively of total respondents (N=125). The small herd size and the relatively good weather (Figure 17) that ensured availability of some forages throughout the year might have contributed to this observation. However, it could also be due to the communal land tenure system whereby individual farmers do not feel compelled about the quality of grazing land or other sources of fodder that are held as common goods. The case where cattle keepers felt irresponsible in taking care of pastures and other resources was reported by Düvel (1998) whereby South African cattle keepers were interested in maximizing gains of own stock on the rangeland at the expense of deteriorating resource base.

4.4 Forage potential, feeding, utilization and production response of cattle

The basis of selecting and use of different forage species were determined through PRA sessions or group interviews as detailed in the following sub-sections.

4.4.1 Designation of criteria through group interviews

Criteria used by farmers in evaluating qualities of forages varied from those based on primary purposes of keeping cattle such as need for more milk for sales to those associated with farmers' and animal welfare (Table 23). These criteria were applicable in accordance with the general terms of quality description discussed earlier (Table 19). The criteria for forage quality were:

- (1) Preference by cattle [the extent the animal craved for the offered species]
- (2) Increase in milk yield
- (3) Stomach fill (determined through visual observation – size of belly and quantity and quality of forages in the vicinity)
- (4) Availability
- (5) Absence of feeding disorders [disorders that were usually noted in a short term - i.e. in a day or two) – e.g. diarrhea) and / or bloat]
- (6) High milk quality [was associated with more cream or less whey]
- (7) Healthy animal [was associated with general condition on continued feeding]
- (8) Easiness in cut and carry [Convenience in harvesting].

4.4.2 Local assessment and procedures for forage quality description

Physical measurement and visual assessment of situations in daily management of cattle (e.g. cows) were used to designate criteria for forage quality. For example, daily milk yield (quantity of milk obtained after morning and / or evening milking) would be considered in view of how the cow was fed. Any deviation was therefore considered in relation to her normal records (based on memory or written, which was rare). In order to know whether the animal is satisfied (also referred to as stomach filled), farmers (or herdsman) normally assess the amount of feed that is left in the manger (under stall fed conditions) and the general animal behaviour.

Table 23. Criteria used in ranking forage species under zero grazing conditions

Criteria	Basis for farmers in assessing criteria
Palatability	<ul style="list-style-type: none"> ▪ Time taken for cattle to eat and finish up the amount of forages offered. ▪ Behaviour when the animal is given (or finds) the forage e.g. going towards or away from forage, “concentrates” or is enthusiastic at eating, not bellowing.
Stomach fill	<ul style="list-style-type: none"> ▪ Physical size of the belly. ▪ Animal behaviour as signs for satisfaction e.g. standing idle or lying down. ▪ Quantity and quality of feed in the vicinity (e.g. forage remaining in the manger). ▪ Stage of maturity (neither too succulent nor too mature).
Amount (Yield) of milk	<ul style="list-style-type: none"> ▪ Increase or decrease in the amount of milk produced per milking.
Quality of milk	<ul style="list-style-type: none"> ▪ Smell (odour) detected in milk if fed with particular forage ▪ Amount of fat (cream) and whey found when milk used in tea or when it is fermented). Farmers used terms ‘heaviness’ / ‘lightness’ of milk produced.
Availability	<ul style="list-style-type: none"> ▪ Distribution of specific species among other species available in the area. ▪ Ease of obtaining specific species in a season (dry / wet) or throughout the year. ▪ Distance from residence to place where forages are collected.
Others	<ul style="list-style-type: none"> ▪ Growth of young animals in a specific period of time
(i) Production and health of animals	<ul style="list-style-type: none"> ▪ Weights put up (or maintained for adults) in a referred time period (e.g. season or year). ▪ Smooth skin and turgid body condition when consumed. ▪ Absence of (or available) records of deaths due to poisoning ▪ Absence of feeding disorders (e.g. Diarrhoea or bloat when consumed).
(ii) Convenience on harvest	<ul style="list-style-type: none"> ▪ Easy to cut and carry ▪ Stage of maturity ▪ Height ▪ Absence or presence of spines that itch / irritate for easy handling and / or carrying (on head, bicycle).

Physical assessment of quality and quantity of feeds accessible to the animal was usually used as a reference if the animal was standing or lying idle or if he/she remains quiet (no bellowing) and lies down to chew the cud. These behavioural

observations reported by farmers are similar to other reports whereby behavioural and intake experiments have also indicated that physical signals (rumen fill) and chemical and metabolic signals influence intake and the satiation processes in ruminants (Fernandez *et al.*, 2004). Under confinement feeding situations the term *ad lib* is used when enough feed is offered so that the animal could eat any time if it wanted to.

Farmers' reflections on the quality of milk were based on the amount of cream or whey in fresh and fermented milk in which case creamy milk was considered to be of high quality. Actually, some farmers practised the traditional processing and consuming of acidified milks that is dominant in the Southern and East African region (FAO, 1990). This involved removal of whey in coagulated milks and drinking or eating the product either separately or with other foods. However, many cattle owners or their clients used whole milk and mostly drank milk in beverages such as tea or coffee. Although farmers' arguments about the amount of cream and whey in the milk produced after feeding of specific forages could be valid, this may not be the only factor associated with grasses or legumes alone. Milk quality varies with breed of the lactating animal and the stage of lactation (FAO, 1990; McDonald *et al.*, 1998) whereby high yielding cows have lowest contents of fat and protein. But it has been documented too (Pirisi *et al.*, 2004) that the composition of milk is a function of the overall nutrition of the lactating animal including the basal diet and (or) the supplements provided. DePeters and Cant (1992) also noted that altering the forage:concentrate ratio, type and composition of concentrate or processing method

affects the overall fermentation balance of the carbohydrates and the acids produced and hence the quality of milk and milk products produced.

Farmers also determine the influence of various forage species on productivity of animals on the basis of milk yield (lactating cows) and health of animals in a herd. While it was argued that it was easier to note increase or decrease of the amount of milk produced when particular forage materials were harvested and given as feed, the health status of animals would be determined through such factors as direct visual observation of how the animal looks and smoothness of the hair or indirectly through decrease in milk yield. Much as the decrease in milk yield on a particular day would be due to physiological (e.g. a cow being on heat) and nutritional factors (Sutton and Morant, 1989; McDonald *et al.*, 1998) it was imperative for a farmer to be vigilant enough so as to ascertain that any discrepancy from normal yields could be due to particular forages offered.

However, it was reported that there were forage materials that contain toxic substances, and these were considered to be of bad quality. These include, for example, wild sorghums locally known as '*Mtama pori*' (*Sorghum* spp), cassava leaves (*Manihot esculentum*), leaves of the ceara rubber (or tree cassava, *Manihot glaziovii*) and other leguminous plants. It was recognised that toxicity would be encountered particularly when the forages are fed excessively. Fortunately, however, no single case of cattle deaths was reported in the study villages due to feeding on poisonous forages. Nevertheless, farmers who had included wild sorghums in

feeding remarked that wild sorghum had a bitter taste, the fact that led them to reduce the amount of wild sorghums whenever it was offered to cattle.

Palatability of grasses, legumes or forbs was another factor for quality description. Farmers' comparison of the different classes of forages revealed that legume and forb species were more palatable than grass forages (Table 24).

The Kiswahili terms used by farmers in qualitative and quantitative comparison of legumes/forbs with grass forages were *mboga* vs. *ugali*. In this regard, legumes and forbs were viewed as relish (*mboga*) while grasses were equated to the main dish (*ugali*). According to farmers, a relish is tasty but cannot provide desirable stomach fill when compared to the main course, *ugali*, a maize meal that is a common food in East and Central Africa. In the same way, therefore, farmers argued that legumes and forbs would not be sufficient on their own to provide the satisfactory quantities of the daily DM intake of an animal. However, grasses could provide almost all the amount of DM needed if offered alone. Intuitively, legumes and forbs were hailed in the role they play as protein rich feeds especially in these low input–low output systems where commercial proteins and mineral supplements are scantily utilized because they are not available and are relatively expensive when available.

Table 24. Pairwise ranking of palatability of various forage species in Kichangani village

Forage spp*	Magugu	Nyasi	Masinde	Kunde pori	Kongo	Tem. pori	Tembele	Score	Rank
Magugu	=====	Magugu	Masinde	Kunde pori	Kongo	Tem. pori	Tembele	1	6
Nyasi	=====	=====	Masinde	Kunde pori	Kongo	Tem. pori	Tembele	0	7
Masinde	=====	=====	=====	Kunde pori	Kongo	Tem. pori	Tembele	2	5
Kunde pori	=====	=====	=====	=====	Kunde pori	Kunde pori	Kunde pori	6	1
Kongo	=====	=====	=====	=====	=====	Tem. pori	Tembele	4	4
Tem. pori	=====	=====	=====	=====	=====	=====	Tembele	5	3
Tembele	=====	=====	=====	=====	=====	=====	=====	5	2

*Binomial nomenclature is as indicated in Table 20.

Discussion with individual cattle keepers or in groups (Plate 6, 7 and 8) with regard to clarification about palatability showed that under zero grazing situation the most palatable species *would be craved for or was more voluntarily eaten by animals than the less palatable ones*. Under free grazing, however, it was argued that *the animals would run for that species and in mixed sward the species would be selected first*. Similarly, remarks that some grass species fed to cattle were 'sweeter' than others and thus more favoured also agrees with the observation made by Forbes (1995). Most of the farmers who use maize stover in green forms reported that these materials have a sweet taste like *P. purpureum*, and when brought to the animal or grazed upon they are readily eaten. The farmers' arguments were consistent with those of Foster *et al.* (2002) that acceptance or preference of given herbage is a result of availability, physical and chemical characteristics of the plant material. In most cases, preferences are determined in cafeteria trials (Lizarraga-Sánchez *et al.*, 2001; Foster *et al.*, 2002). On the other hand, Forbes (1995) observed that there were varying ways of measuring palatability, just as there are various ways of defining the term. These ways range from quantitative measurements of distribution of various species within the sward to qualitative determinations of chemical composition and digestibility of individual forage species or diets.



Plate 6. An eighty-year-old farmer from Lungo village, Mr Ndesario (right) pictured with the researcher (left).



Plate 7. Some of the participants in a group discussion in Kidudwe village.



Plate 8. Some of the participants in a group discussion in Lungo village.

4.4.3 Assessment of forage quality through longitudinal survey

4.4.3.1 Descriptive statistics for grass forages

Frequencies and percent frequencies of ranking various grass species based on local quality criteria are shown in Table 25 to Table 32. Generally, farmers were contented with acceptability of the grasses they collected for their cows such that ranking of grasses on preference criterion for both good and very good order was respectively expressed to be 38.4% and 44.8% (N = 125), 37.3% and 50.0% (N=142), 46.4% and 49.0% (N = 153) and 52.4% and 45.8% (N = 168) in seasons 1, 2, 3 and 4 (Table 25). The frequent use of few species was also demonstrated. For example, the frequent use of *P. maximum* for 24%, 21%, 20% and 18% of all responses on animal preference compared to 4%, 5%, 9% and 10% for *Digitaria* spp in seasons 1, 2, 3 and 4 respectively (Table 25).

The rating of grasses in other quality criteria followed a similar trend to the preference criterion. In the high milk criterion, the majority of farmers (> 40%) ranked the selected grass species as 'good' (Table 26). In all seasons, *P. maximum* and *P. purpureum* were in alternating high ranks for the milk yield criterion. *R. cochinchinensis*, *Cynodon* spp and *Digitaria* spp were the only forage that were considered to be very poor in stomach fill criterion whereby this contributed to 15.2% of the total responses in season 1 and 13.4 % in season 2 (Table 27). Individually, however, *R. cochinchinensis* was rated very poor by as high as 76% (N = 16) of all the responses in season one. On the other hand, *P. maximum* and *P.*

purpureum attained a higher rank for the stomach fill criterion. Other associated criteria such as availability (Table 28) and convenience (Table 32) also contributed to higher or lower ranking of a particular species in specific criterion such as stomach fill because farmers consider a combination of factors in each instance but not in isolation.

If feeding of a particular grass species was unlikely to lead to diarrhoea or bloat this criterion for quality was generally referred to as 'absence of feeding disorders'. The overall ranking with respect to this criterion showed that responses varied from 22.4% to 63.6% in good or very good ranks through the four seasons (Table 29). *R. cochinchinensis* was considered to be very poor in season 1 and 2 where it was rated to be very poor by as high as 67% of respondents. In general, however, individual scores of the grass species for the unsuitability of the forages (poor or very poor) were very low suggesting that farmers were very sensitive in the selection of forages that would suit their production targets and minimise cost of production.

Responses for suitability of the grass species on their effect on health condition showed that the seven species were generally suitable as indicated by 38.4% and 42.4%; 54.9 and 23.9%; 66.2 and 27.3% and 59.5 and 35.1% for good and very good rating respectively throughout the four seasons (Table 30). Meanwhile, there were inter-relationships of views of rating the species on the health aspect and other criteria whereby 71.4% rated *R. cochinchinensis* as very poor in season 2 (Table 30). This could be due to its correspondingly low rate of availability (Table 28).

Producing milk of desirable quality was a priority of all farmers such that they barely used forages that would fail them to reach or attain their goal. This was evident in a few cases reported over the four survey seasons whereby between 1% and 15% of responses on all the forages were rated poor to very poor on milk quality (Table 31). In most of these cases, however, the responses were associated with forages obtained seasonally.

Up to 81% of respondents (N = 20) considered that *R. cochinchinensis* was the most difficult (very inconvenient) species to handle especially during the dry season (Table 32). Similarly, between 21% and 57% of the respondents reported similar observations in regard to *Cynodon* and *Digitaria* spp. Although plant characteristics such as the hairy or itchy leaf surface of *R. cochinchinensis* and lower growth heights of *Cynodon* and *Digitaria* spp led to negative rating of these grasses in the convenience aspects, farmers were generally satisfied with the grass species they frequently used.

Table 25. Frequency (Percentage*) of ranking various grass species based on animal preference criterion by seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	0	0	14 (70.0)	0	2 (14.3)	1 (20.0)	0	17 (13.6)
	poor	0	0	3 (15.0)	1 (5.3)	0	0	0	4 (3.2)
	good	4 (14.8)	19 (63.3)	1 (5.0)	10 (52.6)	10 (71.4)	1 (20.0)	3 (30.0)	48 (38.4)
	very good	23 (85.2)	11 (36.7)	2 (10.0)	8 (42.1)	2 (14.3)	3 (60.0)	7 (70.0)	56 (44.8)
	Total**	27 (21.6)	30 (24.0)	20 (16.0)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100)
2	very poor	0	0	14 (66.7)	0	2 (8.7)	0	0	16 (11.3)
	poor	0	0	6 (28.6)	2 (8.79)	4 (17.4)	3 (42.9)	1 (10.0)	16 (11.3)
	good	7 (25.0)	7 (23.3)	1 (4.8)	20 (87.0)	12 (52.2)	2 (28.6)	4 (40.0)	53 (37.3)
	very good	21 (75)	23 (76.7)	0	1 (4.4)	5 (21.7)	2 (28.6)	5 (50.0)	57 (50.0)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.93)	10 (7.04)	142 (100)

Table 25. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	1 (7.1)	0	1 (0.7)
	poor	0	0	3 (12.0)	1 (4.0)	1 (4.4)	1 (7.1)	0	6 (3.9)
	good	2 (7.4)	3 (10.0)	17 (68.0)	18 (72.0)	17 (73.9)	9 (64.3)	5 (55.6)	71 (46.4)
	very good	25 (92.6)	27 (90)	5 (20.0)	6 (24.0)	5 (21.7)	3 (21.4)	4 (44.4)	75 (49.0)
Total**		27 (17.7)	30 (19.6)	25 (16.3)	25 (16.3)	23 (15.0)	14 (9.2)	9 (5.9)	153 (100)
4	very poor	0	0	0	0	0	1 (5.9)	0	1 (0.6)
	poor	0	0	1 (3.5)	1 (3.5)	0	0	0	2 (1.2)
	good	4 (13.8)	2 (6.7)	24 (82.8)	22 (75.9)	20 (80.0)	13 (76.5)	3 (33.3)	88 (52.4)
	very good	25 (86.2)	28 (93.3)	4 (13.8)	6 (20.7)	5 (20.0)	3 (17.7)	6 (66.7)	77 (45.8)
Total**		29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
3. Short rain (December / January) 4. Long rain (April / May)Grass species: I = *Pennisetum purpureum*II = *Panicum maximum*III = *Rotboellia cochinchinensis*IV = *Panicum trichocladium*V = *Cynodon* sppVI = *Digitaria* sppVII = *Trypsacum laxum*

Table 26. Frequency (Percentage*) of ranking various grass species for effect on milk yield in different seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	0	0	15 (75.0)	0	2 (14.3)	2 (40.0)	0	19 (15.2)
	poor	0	0	2 (10.0)	1 (5.3)	1 (7.1)	0	0	4 (3.2)
	good	9 (33.3)	19 (63.3)	2 (10.0)	13 (68.4)	8 (57.1)	2 (40)	3 (30)	56 (44.8)
	very good	18 (66.7)	11 (36.7)	1 (5.0)	5 (26.3)	3 (21.4)	1 (20.0)	7 (70)	46 (36.8)
	Total**	27 (21.6)	30 (24)	20 (16.0)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100)
2	very poor	0	0	16 (76.2)	0	2 (8.7)	0	0	18 (12.7)
	poor	0	0	3 (14.3)	3 (13.0)	4 (17.4)	4 (57.1)	1 (10.0)	15 (10.6)
	good	11 (39.3)	12 (40.0)	2 (9.5)	20 (87.0)	17 (73.9)	3 (42.9)	3 (30.0)	68 (47.9)
	very good	17 (60.7)	18 (60.0)	0	0	0	0	6 (60)	41 (28.9)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.9)	10 (7.0)	142 (100)

Table 26. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	1 (7.1)	0	1 (0.7)
	poor	0	0	5 (12.0)	1 (3.9)	1 (4.4)	1 (7.1)	0	6 (3.9)
	good	5 (18.5)	5 (16.7)	16 (64.0)	21 (80.8)	20 (87.0)	11 (78.6)	3 (33.3)	81 (52.6)
	very good	22 (81.5)	25 (83.3)	6 (24.0)	4 (15.4)	2 (8.7)	1 (7.1)	6 (66.7)	66 (42.86)
Total**		27 (17.5)	30 (19.5)	25 (16.2)	26 (16.9)	23 (14.9)	14 (9.1)	9 (5.8)	154 (100)
4	very poor	0	0	1 (3.5)	1 (3.5)	0	1 (5.9)	0	3 (1.8)
	poor	0	0	4 (13.8)	3 (10.3)	1 (4.0)	0	0	8 (4.8)
	good	9 (31.0)	5 (16.7)	17 (58.6)	22 (75.9)	21 (84.0)	14 (82.4)	4 (44.4)	92 (54.76)
	very good	20 (69.0)	25 (83.3)	7 (24.1)	3 (10.3)	3 (12.0)	2 (11.8)	5 (55.6)	65 (38.7)
Total**		29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
 3. Short rain (December / January) 4. Long rain (April / May)

Grass species: I = *Pennisetum purpureum* II = *Panicum maximum*

III = *Rotboellia cochinchinensis* IV = *Panicum trichocladum*

V = *Cynodon* spp

VI = *Digitalia* spp

VII = *Trypsaicum laxum*

Table 27. Frequency (Percentage*) of ranking various grass species for effect on stomach fill in different seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	0	0	15 (75.0)	0	2 (14.3)	2 (40.0)	0	19 (15.2)
	poor	0	0	2 (10.0)	3 (15.8)	0	0	0	5 (4.0)
	good	7 (25.9)	14 (46.7)	1 (5.0)	15 (79.0)	10 (71.4)	3 (60.0)	5 (50.0)	55 (44.0)
	very good	20 (74.1)	16 (53.3)	2 (10.0)	1 (5.3)	2 (14.3)	0	5 (50)	46 (36.8)
	Total**	20 (21.6)	30 (24.0)	20 (16.0)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100)
2	very poor	0	0	16 (76.2)	1 (4.4)	2 (8.7)	0	0	19 (13.4)
	poor	0	0	3 (14.3)	7 (30.4)	6 (26.1)	4 (57.1)	2 (20.0)	22 (15.5)
	good	11 (39.3)	12 (40.0)	2 (9.5)	15 (65.2)	15 (65.2)	3 (42.9)	5 (50.0)	63 (44.37)
	very good	17 (60.7)	18 (60.0)	0	0	0	0	3 (30.0)	38 (26.8)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.9)	10 (7.0)	142 (100)

Table 27. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	1 (7.1)	0	1 (0.6)
	poor	0	0	3 (12.0)	3 (11.5)	2 (8.7)	4 (28.6)	0	12 (7.8)
	good	5 (18.5)	7 (23.3)	20 (80.0)	20 (76.9)	20 (87.0)	8 (57.1)	7 (77.8)	87 (56.5)
	very good	22 (81.5)	23 (76.7)	2 (8.0)	3 (11.5)	1 (4.4)	1 (7.1)	2 (22.2)	54 (35.1)
	Total**	27 (17.5)	30 (19.5)	25 (16.2)	26 (16.9)	23 (14.9)	14 (9.1)	9 (5.8)	154 (100)
4	very poor	0	0	2 (6.9)	2 (6.9)	1 (4.0)	2 (11.8)	0	7 (4.2)
	poor	0	0	3 (10.3)	4 (13.8)	3 (12.0)	3 (17.7)	0	13 (7.7)
	good	8 (27.6)	5 (16.7)	24 (82.8)	21 (72.4)	19 (76.0)	10 (58.8)	6 (66.7)	93 (55.36)
	very good	21 (72.4)	25 (83.3)	0	2 (6.9)	2 (8.0)	2 (11.8)	3 (33.3)	55 (32.7)
	Total**	29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
3. Short rain (December / January) 4. Long rain (April / May)Grass species: I = *Pennisetum purpureum* II = *Panicum maximum*
III = *Rotboellia cochinchinensis* IV = *Panicum trichocladium*
V = *Cynodon* spp VI = *Digitaria* spp VII = *Trypsacum laxum*

Table 28. Frequency (Percentage*) of ranking various grass species on availability in different seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	0	1 (3.33)	14 (70)	3 (15.8)	2 (14.3)	3 (60)	1 (10)	24 (19.2)
	poor	4 (14.81)	0	3 (15.0)	2 (10.5)	2 (14.3)	0	4 (40.0)	15 (12.0)
	good	13 (48.2)	17 (56.7)	2 (10.0)	10 (52.6)	6 (42.9)	1 (20.0)	5 (50.0)	54 (43.2)
	very good	10 (37.0)	12 (40.0)	1 (5.0)	4 (21.1)	4 (28.6)	1 (20.0)	0	32 (25.6)
	Total**	27 (21.6)	30 (24.0)	20 (16.0)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100.0)
2	very poor	0	0	16 (76.2)	0	2 (8.7)	0	1 (10.0)	19 (13.38)
	poor	3 (10.7)	1 (3.33)	3 (14.3)	7 (30.4)	8 (34.8)	4 (57.1)	5 (50.0)	31 (21.8)
	good	13 (46.4)	15 (50.0)	1 (4.8)	16 (69.6)	13 (56.5)	3 (42.9)	4 (40)	65 (45.8)
	very good	12 (42.9)	14 (46.7)	1 (4.8)	0	0	0	0	27 (19)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.9)	10 (7.0)	142 (100)

Table 28. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	1 (7.1)	0	1 (0.7)
	poor	0	0	6 (24.0)	3 (11.5)	5 (21.7)	3 (21.4)	3 (33.3)	20 (13.0)
	good	14 (51.9)	10 (33.3)	11 (44.0)	20 (76.9)	18 (78.3)	10 (71.4)	6 (66.7)	89 (57.8)
	very good	13 (48.2)	20 (66.7)	8 (32.0)	3 (11.5)	0	0	0	44 (28.6)
Total**		27 (17.5)	30 (19.5)	25 (16.2)	26 (16.9)	23 (14.9)	14 (9.1)	9 (5.8)	154 (100)
4	very poor	0	0	3 (10.3)	1 (3.5)	1 (4.0)	2 (11.8)	3 (33.3)	10 (6.0)
	poor	3 (10.3)	0	3 (10.3)	3 (10.3)	3 (12.0)	3 (17.6)	1 (11.1)	16 (9.5)
	good	12 (41.4)	6 (20.0)	22 (75.9)	22 (75.9)	21 (84.0)	12 (70.6)	5 (55.6)	100 (59.5)
	very good	14 (48.3)	24 (80.0)	1 (3.45)	3 (10.34)	0	0	0	42 (25.0)
Total**		29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons:

1. Cool / Dry (July / August)
2. Dry (September / October)
3. Short rain (December / January)
4. Long rain (April / May)

Grass species:

- I = *Pennisetum purpureum*
- II = *Panicum maximum*
- III = *Roiboaella cochinchinensis*
- IV = *Panicum trichocladium*
- V = *Cynodon* spp
- VI = *Digitaria* spp
- VII = *Trypsacum laxum*

Table 29. Frequency (Percentage*) of ranking various grass species on diarrhoea or bloat free in different seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	1 (3.7)	1 (3.3)	13 (65.0)	1 (5.3)	3 (21.4)	2 (40.0)	1 (10.0)	22 (17.6)
	poor	0	0	1 (5.0)	0	0	0	1 (10.0)	2 (1.6)
	good	3 (11.1)	10 (33.3)	1 (5.0)	6 (31.6)	4 (28.6)	1 (20.0)	3 (30.0)	28 (22.4)
	very good	23 (85.2)	19 (63.3)	5 (25)	12 (63.2)	7 (50.0)	2 (40.0)	5 (50.0)	73 (58.4)
	Total**	27 (21.6)	30 (24.0)	20 (100)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100)
2	very poor	0	0	14 (66.7)	0	2 (8.7)	0	0	16 (11.3)
	poor	0	0	2 (9.5)	4 (8.7)	4 (17.4)	2 (28.6)	1 (10.0)	11 (7.8)
	good	15 (53.6)	12 (40.0)	3 (14.3)	16 (69.6)	13 (56.5)	3 (42.9)	5 (50.0)	67 (50.0)
	very good	13 (46.4)	18 (60.0)	2 (9.5)	5 (21.7)	4 (17.4)	2 (28.6)	4 (40.0)	48 (40.0)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.9)	10 (7.0)	142 (100)

Table 29. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	0	0	0
	poor	0	0	4 (16.0)	3 (11.5)	2 (8.7)	2 (14.3)	0	11 (7.1)
	good	13 (48.2)	10 (33.3)	17 (68.0)	19 (73.1)	19 (82.6)	12 (85.7)	8 (88.9)	98 (63.6)
	very good	14 (51.9)	20 (66.7)	4 (16.0)	4 (15.4)	2 (8.7)	0	1 (11.1)	45 (29.2)
	Total**	27 (17.5)	30 (19.5)	25 (16.2)	26 (16.9)	23 (14.9)	14 (9.1)	9 (5.8)	154 (100)
4	very poor	0	0	0	0	0	0	0	0
	poor	0	0	3 (10.3)	2 (6.9)	1 (4.0)	1 (5.9)	0	7 (4.2)
	good	14 (48.3)	10 (33.3)	17 (58.6)	17 (58.6)	15 (60.0)	10 (58.8)	6 (66.7)	89 (53.0)
	very good	15 (51.7)	20 (66.7)	9 (31.0)	10 (34.5)	9 (36.0)	6 (35.3)	3 (33.3)	72 (42.9)
	Total**	29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
3. Short rain (December / January) 4. Long rain (April / May)Grass species: I = *Pennisetum purpureum* II = *Panicum maximum*
III = *Rotboellia cochinchinensis* IV = *Panicum trichocladium*
V = *Cynodon* spp VI = *Digitaria* spp VII = *Trypsacum laxum*

Table 30. Frequency (Percentage*) of ranking grass species on effect on general health condition in different seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	0	1 (3.3)	14 (70.0)	1 (5.3)	1 (7.1)	2 (40)	0	19 (15.2)
	poor	0	0	3 (15.0)	1 (5.3)	0	0	1 (10.0)	5 (4.0)
	good	11 (40.7)	14 (46.7)	2 (10.0)	7 (36.8)	9 (64.3)	0	5 (50.0)	48 (38.4)
	very good	16 (59.3)	15 (50.0)	1 (5.0)	10 (52.6)	4 (28.6)	3 (60.0)	4 (40.0)	53 (42.4)
	Total**	27 (21.6)	30 (24.0)	20 (16.0)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100)
2	very poor	0	0	15 (71.4)	1 (4.4)	3 (3)	0	0	19 (13.4)
	poor	0	0	3 (14.3)	3 (13.0)	3 (13.0)	2 (28.6)	0	11 (7.8)
	good	14 (50.0)	14 (46.7)	3 (14.3)	18 (78.3)	16 (69.6)	5 (71.4)	8 (80.0)	78 (54.9)
	very good	14 (50.0)	16 (53.3)	0	1 (4.4)	1 (4.4)	0	2 (20.0)	34 (23.9)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.9)	10 (7.0)	142 (100)

Table 30. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	1 (7.1)	0	1 (0.6)
	poor	0	0	4 (16.0)	2 (7.7)	2 (8.7)	1 (7.1)	0	9 (5.8)
	good	11 (40.7)	11 (36.7)	19 (76.0)	21 (80.8)	20 (87.0)	12 (85.7)	8 (88.9)	102 (66.2)
	very good	16 (59.3)	19 (63.3)	2 (8.0)	3 (11.5)	1 (4.4)	0	1 (11.1)	42 (27.3)
Total**		27 (17.5)	30 (19.5)	25 (16.2)	26 (16.9)	23 (14.9)	14 (9.1)	9 (5.8)	154 (100)
4	very poor	0	0	2 (6.9)	0	0	1 (5.9)	0	3 (1.8)
	poor	0	1 (3.3)	3 (10.3)	1 (3.5)	1 (4.0)	0	0	6 (3.6)
	good	10 (34.5)	7 (23.3)	21 (72.4)	25 (79.3)	20 (80.0)	12 (70.6)	7 (77.8)	100 (59.5)
	very good	19 (65.5)	22 (73.3)	3 (10.3)	5 (17.2)	4 (16.0)	4 (23.5)	2 (22.2)	59 (35.1)
Total**		29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)

3. Short rain (December / January) 4. Long rain (April / May)

Grass species: I = *Pennisetum purpureum* II = *Panicum maximum*III = *Rotboellia cochinchinensis* IV = *Panicum trichocladium*V = *Cynodon* spp VI = *Digitaria* spp VII = *Trypsacum laxum*

Table 31. Frequency (Percentage*) of ranking various grass species on effect on milk quality in different seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	0	0	14 (70.0)	1 (5.3)	2 (14.3)	2 (40.0)	0	19 (15.2)
	poor	0	0	2 (10.0)	1 (5.3)	1 (7.1)	0	0	4 (3.2)
	good	11 (40.7)	13 (43.3)	2 (10.0)	5 (26.3)	6 (42.9)	0	4 (40.0)	41 (32.8)
	very good	16 (59.3)	17 (56.7)	2 (10.0)	12 (63.2)	5 (35.7)	3 (60.0)	6 (60.0)	61 (48.8)
	Total**	27 (21.6)	30 (24.0)	20 (16.0)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100)
2	very poor	0	0	16 (76.2)	1 (4.4)	3 (13.0)	0	0	20 (14.1)
	poor	1 (3.6)	0	2 (9.5)	2 (8.7)	3 (13.0)	2 (28.6)	0	10 (7.0)
	good	15 (53.6)	14 (46.7)	3 (14.3)	19 (82.6)	16 (69.6)	5 (71.4)	9 (90.0)	81 (57.0)
	very good	12 (42.9)	16 (53.3)	0	1 (4.4)	1 (4.4)	0	1 (10.0)	31 (21.8)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.9)	10 (7.0)	142 (100)

Table 3 I. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	1 (7.1)	0	1 (0.7)
	poor	0	0	4 (16.0)	1 (3.9)	2 (8.7)	2 (14.3)	0	9 (5.8)
	good	14 (51.9)	13 (43.3)	19 (76.0)	21 (80.8)	18 (78.3)	10 (71.4)	9 (100)	104 (67.5)
	very good	13 (48.2)	17 (56.7)	2 (8.0)	4 (15.4)	3 (13.0)	1 (7.1)	0	40 (26.0)
Total**		27 (17.5)	30 (19.5)	25 (16.2)	26 (16.9)	23 (14.9)	14 (9.1)	9 (5.8)	154 (100)
4	very poor	0	0	1 (3.5)	0	0	1 (5.9)	0	2 (1.2)
	poor	0	1 (3.3)	3 (10.3)	2 (6.9)	1 (4.0)	1 (5.9)	0	8 (4.8)
	good	17 (58.6)	9 (30.0)	21 (72.4)	23 (79.3)	21 (84.0)	12 (70.6)	8 (88.9)	111 (66.1)
	very good	12 (41.4)	20 (66.7)	4 (13.8)	4 (13.8)	3 (12.0)	3 (17.7)	1 (11.1)	47 (28.0)
Total**		29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)

3. Short rain (December / January) 4. Long rain (April / May)

Grass species: I = *Pennisetum purpureum*II = *Panicum maximum*III = *Roiboaella cochinchinensis*IV = *Panicum trichocladium*V = *Cynodon* sppVI = *Digitaria* sppVII = *Trypsacum laxum*

Table 32. Frequency (Percentage*) of ranking various grass species for convenience in handling in different seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	0	0	15 (75.0)	1 (5.3)	2 (14.3)	2 (40.0)	0	20 (16.0)
	poor	0	1 (3.3)	2 (10.0)	3 (15.8)	2 (14.3)	0	0	8 (6.4)
	good	8 (29.6)	15 (50.0)	2 (10.0)	6 (31.6)	5 (35.7)	1 (20.0)	5 (50.0)	42 (33.6)
	very good	19 (70.4)	14 (46.7)	1 (5.0)	9 (47.4)	5 (35.7)	2 (40.0)	5 (50.0)	55 (44.0)
	Total**	27 (21.6)	30 (24.0)	20 (16.0)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100)
2	very poor	0	0	17 (81.0)	1 (4.4)	2 (8.7)	0	0	20 (14.1)
	poor	0	0	3 (14.3)	6 (26.1)	3 (13.0)	4 (57.1)	3 (30.0)	19 (13.4)
	good	18 (64.3)	17 (56.7)	1 (4.8)	16 (69.6)	18 (78.3)	3 (42.9)	6 (60.0)	79 (55.6)
	very good	10 (35.7)	13 (43.3)	0	0	0	0	1 (10.0)	24 (16.9)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.9)	10 (7.0)	142 (100)

Table 32. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	1 (7.1)	0	1 (0.6)
	poor	0	0	11 (41.0)	6 (23.1)	5 (21.7)	2 (14.3)	0	24 (15.6)
	good	12 (44.4)	13 (43.3)	13 (52.0)	18 (69.2)	18 (78.3)	11 (78.6)	9 (100)	94 (61.0)
	very good	15 (55.6)	17 (56.6)	1 (4.0)	2 (7.7)	0	0	0	35 (22.7)
Total**		27 (17.5)	30 (19.5)	25 (16.2)	26 (16.9)	23 (14.9)	14 (9.1)	9 (5.8)	154 (100)
4	very poor	0	0	3 (10.3)	0	0	1 (5.9)	0	4 (2.4)
	poor	0	0	8 (27.6)	5 (17.2)	5 (20.0)	3 (17.7)	0	21 (12.5)
	good	15 (51.7)	11 (36.7)	16 (55.2)	21 (72.4)	19 (76.0)	12 (70.6)	8 (88.9)	102 (60.7)
	very good	14 (48.3)	19 (63.3)	2 (6.9)	3 (10.3)	1 (4.0)	1 (5.9)	1 (11.1)	41 (24.4)
Total**		29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)

3. Short rain (December / January) 4. Long rain (April / May)

Grass species: I = *Pennisetum purpureum* II = *Panicum maximum*III = *Rotboellia cochinchinensis* IV = *Panicum trichocladium*V = *Cynodon* sppVI = *Digitaria* spp VII = *Trypocacum laxum*

4.4.3.2 Descriptive statistics for forage legumes and forbs

Table 33 to Table 40 show frequencies of ranking the legumes and forbs on the basis of preference by cattle (extent of craving on offer), high milk yield, fast stomach fill, availability, absence of feeding disorders (diarrhoea or bloat free), high milk quality, general health condition of animal on continued feeding (general) and convenience in cut and carry criteria respectively. Generally, legumes and forbs were considered to be good or very good in terms of their acceptability by the cattle (Table 33) and in other criteria associated with production such as high milk yield. *M. atropurpureum* was the most preferred species as indicated by between 22 and 29% of respondents over the four seasons (Table 33). Similarly, it was the highest-ranking species in all other criteria with *I. aquatica* ranking second to it in influencing high milk yield (Table 34), stomach fill (Table 35) and availability (Table 36). Actually, legumes and forbs were regarded as poor or very poor in stomach fill as indicated by 23.5% and 57.8% in all the forages over the four seasons (Table 35). In this case, *C. africana* and *M. pruriens* were considered poorer than the other forages. There was poor availability of legumes and forbs especially in the dry season (season 2) as indicated by 24% of respondents (Table 36). On the other hand, legumes and forbs species commonly used were not likely to cause feeding disorders as indicated by the good or very good scores in almost all seasons (Table 37). The influence of legumes and forbs on high milk quality (Table 38) and animal health (Table 39) was also reported by many farmers who rated high most of the species. Nevertheless, about 21 % the respondents felt that it was rather inconvenient to cut and carry legumes and forbs (Table 40).

Table 33. Frequency (Percentage*) of ranking forage legumes and forbs based on animal preference criterion by seasons

Season	Rank	Legume or forb					Total
		I	II	III	IV	V	
1	very poor	0	0	0	0	2 (10.0)	2 (2.0)
	poor	0	1 (12.5)	0	0	0	1 (1.0)
	good	4 (14.3)	1 (12.5)	5 (22.7)	8 (40.1)	7 (35.0)	25 (25.5)
	very good	24 (85.7)	6 (75.0)	17 (77.3)	12 (60.0)	11 (55.0)	70 (71.4)
	Total**	28 (28.6)	8 (8.2)	22 (22.5)	20 (20.4)	20 (20.4)	98 (100)
2	very poor	0	0	0	0	2	2 (1.7)
	poor	0	1	0	0	8	9 (7.6)
	good	13 (44.8)	9 (64.3)	17 (63.0)	21 (77.8)	10 (47.6)	70 (59.3)
	very good	16 (55.2)	4 (28.6)	10 (37.09)	6 (22.2)	1 (4.8)	37 (31.4)
	Total**	29 (24.6)	14 (11.9)	27 (22.9)	27 (22.9)	21 (17.8)	118 (100)
3	very poor	0	0	0	0	0	0
	poor	0	0	0	0	0	0
	good	4 (14.8)	5 (22.7)	13 (54.2)	18 (72.0)	17 (73.9)	57 (47.1)
	very good	23 (85.29)	17 (77.3)	11 (45.8)	7 (28.0)	6 (26.1)	64 (52.9)
	Total**	27 (22.3)	22 (18.2)	19 (19.8)	25 (20.7)	23 (19.0)	121 (100)
4	very poor	1 (3.3)	1 (4.2)	0	0	0	2 (1.5)
	poor	0	0	1 (3.9)	1 (3.7)	0	2 (1.5)
	good	4 (13.3)	8 (33.3)	12 (46.2)	18 (66.7)	16 (69.6)	58 (44.6)
	very good	25 (83.3)	15 (62.5)	13 (50.0)	8 (29.6)	7 (30.4)	68 (52.3)
	Total**	30 (23.1)	24 (18.5)	26 (20.0)	27 (20.89)	23 (17.7)	130 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
3. Short rain (December / January) 4. Long rain (April / May)

Forage species: I = *Macroptilium atropurpureum* II = *Vigna pubescens*
III = *Ipomea aquatica* IV = *Commelina africana*
V = *Mucuna pruriens*

Table 34. Frequency (Percentage*) of ranking forage legumes and forbs based on effect on milk yield criterion by seasons

Season	Rank	Forage					Total
		I	II	III	IV	V	
1	very poor	0	0	0	0	1 (5.0)	1 (1.0)
	poor	0	0	0	0	1 (5.0)	1 (1.0)
	good	7 (25.0)	3 (37.5)	11 (50.0)	9 (45.0)	11 (55.0)	41 (41.8)
	very good	21 (75.0)	5 (62.5)	11 (50.0)	11 (55.0)	7 (35.0)	55 (56.2)
	Total**	28 (28.6)	8 (8.2)	22 (22.6)	20 (20.4)	20 (20.4)	98 (100)
2	very poor	0	0	0	0	2 (10.0)	2 (1.7)
	poor	1 (3.5)	0	0	1 (3.7)	8 (40.0)	10 (8.6)
	good	18 (62.0)	10 (71.4)	22 (81.5)	22 (81.5)	10 (50.0)	82 (70.1)
	very good	10 (34.5)	4 (28.6)	5 (18.5)	4 (14.8)	0	23 (19.7)
	Total**	29 (24.8)	14 (12.0)	27 (23.1)	27 (23.1)	20 (17.1)	119 (100)
3	very poor	0	0	0	0	0	0
	poor	0	0	1 (4.2)	0	4 (17.4)	5 (4.1)
	good	7 (25.9)	6 (27.3)	16 (66.7)	22 (88.0)	14 (60.9)	65 (53.7)
	very good	20 (74.1)	16 (72.7)	7 (29.2)	3 (12.0)	5 (21.7)	51 (42.2)
	Total**	27 (22.3)	22 (18.2)	24 (19.8)	25 (20.7)	23 (19.0)	121 (100)
4	very poor	0	0	0	0	0	0
	poor	1 (3.3)	1 (4.2)	0	2 (7.4)	2 (8.7)	6 (4.6)
	good	9 (30.0)	12 (50.0)	18 (69.3)	22 (81.5)	17 (73.9)	78 (60.0)
	very good	20 (66.7)	11 (45.8)	8 (30.8)	3 (11.1)	4 (17.4)	46 (35.4)
	Total**	30 (23.1)	24 (18.5)	26 (20.0)	27 (20.8)	23 (17.7)	130 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
 3. Short rain (December / January) 4. Long rain (April / May)

Forage species: I = *Macroptilium atropurpureum* II = *Vigna pubescens*
 III = *Ipomea aquatica* IV = *Commelina africana*
 V = *Mucuna pruriens*

Table 35. Frequency (Percentage*) of ranking forage legumes and forbs based on stomach fill criterion by seasons

Season	Rank	Legume or forb					Total
		I	II	III	IV	V	
1	very poor	0	0	0	0	1	1 (1.0)
	poor	8 (28.6)	1 (12.5)	2 (9.1)	4 (20.0)	7 (35.0)	22 (22.5)
	good	17 (60.7)	6 (75.0)	15 (68.2)	12 (60.0)	10 (50.0)	60 (61.2)
	very good	3 (10.7)	1 (12.5)	5 (22.7)	4 (20.0)	2 (10.0)	15 (15.3)
	Total**	28 (28.6)	8 (8.2)	22 (22.5)	20 (20.4)	20 (20.4)	98 (100)
2	very poor	0	0	0	0	3 (15.0)	3 (2.6)
	poor	13 (44.8)	9 (64.3)	3 (11.1)	7 (25.9)	12 (60.0)	44 (37.6)
	good	12 (41.4)	5 (35.7)	22 (81.5)	17 (63.0)	5 (25.0)	61 (52.1)
	very good	4 (13.8)	0	2 (7.4)	3 (11.1)	0	9 (7.7)
	Total**	29 (24.8)	14 (12.0)	27 (23.1)	27 (23.1)	20 (17.1)	117 (100)
3	very poor	0	0	0	0	1 (4.4)	1 (0.8)
	poor	17 (63.0)	17 (77.3)	4 (16.7)	16 (64.0)	15 (65.2)	69 (57.0)
	good	8 (29.6)	5 (22.7)	19 (79.2)	9 (36.0)	7 (30.43)	48 (36.7)
	very good	2 (7.4)	0	1 (4.2)	0	0	3 (2.5)
	Total**	27 (22.3)	22 (18.2)	24 (19.8)	25 (20.6)	23 (19.0)	121 (100)
4	very poor	0	0	0	0	0	0
	poor	18 (60.0)	16 (66.7)	8 (30.8)	16 (59.3)	14 (60.9)	72 (55.4)
	good	11 (36.7)	8 (33.3)	13 (50.0)	10 (37.0)	8 (34.8)	50 (38.5)
	very good	1 (3.3)	0	5 (19.2)	1 (3.7)	1 (4.4)	8 (6.2)
	Total**	30 (23.1)	24 (18.5)	26 (20.0)	27 (20.8)	23 (17.7)	130 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)

3. Short rain (December / January) 4. Long rain (April / May)

Forage species: I = *Macroptilium atropurpureum*

II = *Vigna pubescens*

III = *Ipomea aquatica*

IV = *Commelina africana*

V = *Mucuna pruriens*

Table 36. Frequency (Percentage*) of ranking forage legumes and forbs based on seasonal availability

Season	Rank	Legume or forb					Total
		I	II	III	IV	V	
1	very poor	0	0	1 (4.6)	0	5 (25.0)	6 (6.1)
	poor	3 (10.7)	3 (37.5)	1 (4.6)	1 (5.0)	1 (5.0)	9 (9.2)
	good	20 (71.4)	5 (62.5)	11 (50.0)	9 (45.0)	11 (55.0)	56 (57.1)
	very good	5 (17.9)	0	9 (40.9)	10 (50.0)	3 (15.0)	27 (27.6)
	Total**	28 (28.6)	8 (8.2)	22 (22.5)	20 (20.4)	20 (20.4)	98 (100)
2	very poor	0	0	0	0	6	6 (5.1)
	poor	4 (13.8)	4 (28.)	5 (18.5)	7 (25.9)	8 (40.0)	28 (23.9)
	good	20 (69.0)	9 (64.3)	20 (74.1)	18 (66.7)	6 (30.0)	73 (62.4)
	very good	5 (17.2)	1 (7.1)	2 (7.4)	2 (7.4)	0	10 (8.6)
	Total**	29 (24.8)	14 (12.0)	27 (23.1)	27 (23.1)	20 (17.1)	117 (100)
3	very poor	0	0	5 (20.83)	0	1 (4.4)	6 (5.0)
	poor	3 (11.1)	5 (22.7)	5 (20.8)	2 (8.0)	10 (43.5)	25 (20.7)
	good	21 (77.8)	17 (77.3)	13 (54.2)	22 (88.0)	9 (39.1)	82 (67.8)
	very good	3 (11.1)	0	1 (4.2)	1 (4.0)	3 (13.0)	8 (6.6)
	Total**	27 (22.3)	22 (18.2)	24 (19.8)	25 (20.7)	23 (19.0)	121 (100)
4	very poor	0	0	1 (3.9)	0	0	1 (0.8)
	poor	3 (10.0)	3 (12.5)	4 (15.4)	0	6 (26.1)	16 (12.3)
	good	23 (76.7)	20 (83.3)	19 (73.1)	26 (96.3)	15 (65.2)	103 (79.2)
	very good	4 (13.3)	1 (4.2)	2 (7.7)	1 (3.7)	2 (8.7)	10 (7.7)
	Total**	30 (23.1)	24 (18.5)	26 (20.0)	27 (20.8)	23 (17.7)	130 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
 3. Short rain (December / January) 4. Long rain (April / May)
 Forage species: I = *Macroptilium atropurpureum* II = *Vigna pubescens*
 III = *Ipomea aquatica* IV = *Commelina africana*
 V = *Mucuna pruriens*

Table 37. Frequency (Percentage*) of ranking forage legumes and forbs based on absence of feeding disorders in different seasons

Season	Rank	Legume or forb					Total
		I	II	III	IV	V	
1	very poor	2 (7.1)	1 (12.5)	1 (4.6)	1 (5.0)	2 (10.0)	7 (7.1)
	poor	0	0	2	1	0	3 (3.1)
	good	7 (25.0)	1 (12.5)	7 (31.8)	4 (20.0)	0	3 (3.1)
	very good	19 (67.9)	6 (75.0)	12 (54.6)	14 (70.0)	13 (65.0)	64 (65.3)
	Total**	28 (28.6)	8 (8.2)	22 (22.5)	20 (20.4)	20 (20.4)	98 (100)
2	very poor	0	0	0	0	2 (10.0)	2 (1.7)
	poor	0	0	5 (18.5)	3 (11.1)	8 (40.0)	16 (13.7)
	good	22 (75.9)	10 (71.4)	19 (70.4)	19 (70.4)	7 (35.0)	77 (65.8)
	very good	7 (24.1)	4 (28.6)	3 (11.1)	5 (18.5)	3 (17.1)	22 (18.8)
	Total**	29 (24.8)	14 (12.0)	27 (23.1)	27 (23.1)	20 (17.1)	117 (100)
3	very poor	0	0	0	0	0	0
	poor	0	0	1 (4.2)	2 (8.0)	3 (13.0)	6 (5.0)
	good	23 (85.2)	21 (95.5)	23 (95.8)	22 (88.0)	15 (65.2)	104 (86.0)
	very good	4 (14.8)	1 (4.6)	0	1 (4.0)	5 (21.7)	11 (9.1)
	Total**	27 (22.3)	22 (18.2)	24 (19.8)	25 (20.7)	5 (19.0)	121 (100)
4	very poor	0	0	0	0	0	0
	poor	0	0	2	3	2	6 (4.6)
	good	21 (70.0)	18 (75.0)	20 (76.9)	21 (77.8)	15 (65.2)	95 (73.1)
	very good	9 (30.0)	6 (25.0)	5 (19.2)	3 (11.1)	6 (26.1)	29 (22.3)
	Total**	30 (23.1)	24 (18.5)	26 (20.0)	27 (20.7)	23 (17.7)	130 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
3. Short rain (December / January) 4. Long rain (April / May)

Forage species: I = *Macroptilium atropurpureum* II = *Vigna pubescens*
III = *Ipomea aquatica* IV = *Commelina africana*
V = *Mucuna pruriens*

Table 38. Frequency (Percentage*) of ranking forage legumes and forbs based on producing high quality milk

Season	Rank	Legume or forb					Total
		I	II	III	IV	V	
1	very poor	0	0	0	0	2 (10.0)	2 (2.0)
	poor	0	0	1 (4.6)	1 (5.0)	0	2 (2.0)
	good	8 (28.6)	2 (25.0)	7 (31.8)	6 (30.0)	8 (40.0)	31 (31.6)
	very good	20 (71.4)	6 (75.0)	14 (63.6)	13 (65.0)	10 (50.0)	63 (64.3)
	Total**	28 (28.6)	8 (8.2)	22 (22.5)	20 (20.4)	20 (20.4)	98 (100)
2	very poor	0	0	0	0	2 (10.0)	2 (1.7)
	poor	0	0	3 (11.1)	4 (14.8)	7 (35.0)	14 (12.0)
	good	24 (82.8)	13 (92.9)	22 (81.5)	20 (74.1)	11 (55.0)	90 (76.9)
	very good	5 (17.2)	1 (7.1)	2 (7.4)	3 (11.1)	0	11 (9.4)
	Total**	29 (24.8)	14 (12.0)	27 (23.1)	27 (23.1)	20 (17.1)	117 (100)
3	very poor	0	0	0	0	0	0
	poor	0	0	2 (8.3)	4 (16.0)	3 (13.0)	9 (7.4)
	good	17 (63.0)	20 (90.9)	21 (87.5)	20 (80.0)	15 (65.2)	93 (76.9)
	very good	10 (37.0)	2 (9.1)	1 (4.2)	1 (4.0)	5 (21.7)	19 (15.7)
	Total**	27 (22.3)	22 (18.2)	24 (19.8)	25 (20.7)	23 (19.0)	121 (100)
4	very poor	0	1	0	0	1	2 (1.5)
	poor	0	0	2 (7.7)	4 (14.8)	1 (4.35)	7 (5.4)
	good	20 (66.7)	19 (79.2)	20 (76.9)	20 (74.1)	18 (78.3)	97 (74.6)
	very good	10 (33.3)	4 (16.7)	4 (15.4)	3 (11.1)	3 (13.0)	24 (18.5)
	Total**	30 (23.08)	24 (18.5)	26 (20.0)	27 (20.8)	23 (17.7)	130 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)

3. Short rain (December / January) 4. Long rain (April / May)

Forage species: I = *Macroptilium atropurpureum*

II = *Vigna pubescens*

III = *Ipomea aquatica*

IV = *Commelina africana*

V = *Mucuna pruriens*

Table 39. Frequency (Percentage*) of ranking forage legumes and forbs based on general health of cattle in different seasons

Season	Rank	Legume or forb					Total
		I	II	III	IV	V	
1	very poor	0	0	0	1 (5.0)	2 (10.0)	3 (3.1)
	poor	0	0	1 (4.6)	0	0	1 (1.0)
	good	8 (28.6)	1 (12.5)	5 (22.7)	4 (20.0)	6 (30.0)	24 (24.5)
	very good	20 (71.4)	7 (87.5)	16 (72.7)	15 (75.0)	12 (60.0)	70 (71.4)
	Total**	28 (28.6)	8 (8.2)	22 (22.4)	20 (20.4)	20 (20.4)	98 (100)
2	very poor	0	1 (7.1)	0	0	2 (10.0)	3 (2.6)
	poor	0	0	1 (3.7)	1 (3.7)	7 (35.0)	9 (7.7)
	good	25 (86.29)	11 (78.6)	24 (88.9)	23 (85.2)	10 (50.0)	93 (79.5)
	very good	4 (13.8)	2 (14.3)	2 (7.4)	3 (11.1)	1 (5.0)	12 (10.3)
	Total**	29 (24.8)	14 (12.0)	27 (23.1)	27 (23.1)	20 (17.09)	117 (100)
3	very poor	0	0	0	0	0	0
	poor	0	0	2 (8.3)	2 (8.0)	3 (13.0)	7 (5.8)
	good	17 (63.0)	16 (72.7)	21 (87.5)	22 (88.0)	16 (69.6)	92 (76.0)
	very good	10 (37.0)	6 (27.3)	1 (4.2)	1 (4.0)	4 (7.4)	22 (18.2)
	Total**	27 (22.3)	22 (18.2)	24 (19.8)	25 (20.7)	23 (19.0)	121 (100)
4	very poor	0	0	0	0	1 (4.4)	1 (0.8)
	poor	1 (3.3)	1 (4.2)	0	1 (3.7)	1 (4.4)	4 (3.1)
	good	14 (46.7)	16 (66.7)	20 (76.9)	22 (81.5)	18 (78.3)	90 (69.2)
	very good	15 (50.0)	7 (29.2)	6 (23.1)	4 (14.8)	3 (13.0)	35 (26.9)
	Total**	30 (23.1)	24 (18.5)	26 (20.0)	27 (20.8)	23 (17.7)	130 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)

3. Short rain (December / January) 4. Long rain (April / May)

Forage species: I = *Macropitilium atropurpureum*

II = *Vigna pubescens*

III = *Ipomea aquatica*

IV = *Commelina africana*

V = *Mucuna pruriens*

Table 40. Frequency (Percentage*) of ranking forage legumes and forbs convenience in cut and carry criterion

Season	Rank	Legume or forb					Total
		I	II	III	IV	V	
1	very poor	0	0	1 (4.6)	0	6 (30.0)	7 (1.)
	poor	1 (3.6)	0	0	3 (15.0)	2 (10.0)	6 (6.1)
	good	14 (50.0)	4 (50.0)	10 (45.5)	8 (40.0)	5 (25.0)	41 (41.8)
	very good	13 (46.4)	4 (50.0)	11 (50.0)	9 (45.0)	7 (35.0)	44 (44.9)
	Total**	28 (28.6)	8 (8.2)	22 (22.5)	20 (20.4)	20 (20.4)	98 (100)
2	very poor	0	1 (7.1)	0	0	4 (20.0)	5 (4.3)
	poor	3 (10.3)	1 (7.1)	1 (3.7)	4 (14.8)	11 (55.0)	20 (17.1)
	good	24 (82.8)	11 (78.6)	24 (88.9)	21 (77.8)	5 (25.0)	85 (72.7)
	very good	2 (6.9)	1 (7.1)	2 (7.4)	2 (7.4)	0	7 (6.0)
	Total**	29 (24.8)	14 (12.0)	27 (23.1)	27 (23.1)	20 (17.1)	117 (100)
3	very poor	0	0	1 (4.2)	0	1 (4.4)	2 (1.6)
	poor	2 (7.4)	1 (4.6)	9 (37.5)	6 (24.0)	7 (30.4)	25 (20.7)
	good	22 (81.5)	20 (90.9)	13 (54.2)	18 (72.0)	12 (52.2)	85 (70.3)
	very good	3 (11.1)	1 (4.6)	1 (4.2)	1 (4.0)	3 (13.0)	9 (7.4)
	Total**	27 (22.3)	22 (18.2)	24 (19.8)	20 (20.7)	23 (19.0)	121 (100)
4	very poor	0	0	0	0	2 (8.7)	2 (1.5)
	poor	3 (10.0)	1 (4.2)	2 (7.7)	3 (11.1)	5 (21.7)	14 (10.8)
	good	15 (50.0)	17 (70.8)	20 (76.9)	21 (77.8)	14 (60.9)	87 (66.9)
	very good	12 (40.0)	6 (25.0)	4 (15.4)	3 (11.1)	2 (8.7)	27 (20.8)
	Total**	30 (23.1)	24 (18.5)	26 (20.0)	27 (20.8)	23 (17.7)	130 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
 3. Short rain (December / January) 4. Long rain (April / May)

Forage species: I = *Macroptilium atropurpureum* II = *Vigna pubescens*
 III = *Ipomea aquatica* IV = *Commelina africana*
 V = *Mucuna pruriens*

Generally, farmers' socio-economic bases to favour or dislike specific legume/forb species were similar to those that applied in the utilization of grasses. Conveniences at harvesting of legumes, for example, or the impact of legumes/forbs for increased milk yield had similar cost/benefit interpretations to that of grasses available in mixed production systems (see discussion on page 179 -180).

4.4.4 Logistic analysis for grass forages

4.4.4.1 Ranking of grass forages with respect to specific quality criterion

The logistic regression results from the estimation equations that ranked the grass forages on the different quality criteria are presented from Table 41 to Table 44 whereby the coefficients, odds ratio and Z values are presented. The reference grass forage was one of the most abundant and frequently used, *Panicum maximum*. The odds ratios shown were obtained by exponentiating the coefficients of the logistic regression. The odds ratios of the preference with *P. purpureum* and *Digitaria* spp when all species were compared with *P. maximum* decreased (were less than 1) to 52.39% and 42.44% respectively (Table 41). On the other hand, the odds ratios of *R. cochinchinensis*, *Cynodon* spp and *P. trichocladum* and *T. laxum* increased to 5473.48%, 1078.98%, 842.24% and 212.17% respectively. This means that among the six grass species compared with reference to *P. maximum*, *Digitaria* spp was ranked the first and *P. purpureum* ranked the second for being preferred (easily accepted) by animals followed in that order by *T. laxum*, *P. trichocladum*, *Cynodon* spp and *R. cochinchinensis*.

Among the six grass species compared for their influence on high milk yield, *P. purpureum* was ranked the first; *T. laxum* ranked the second while *R. cochinchinensis* was the last. The odds ratios of high milk yield with *P. purpureum* decreased to 85.42% with reference to *P. maximum*. However, the odds ratios increased to 5193.02%, 1854.31%, 1334.58%, 1062.49% and 116.60% with *R. cochinchinensis*, *Digitaria* spp, *Cynodon* spp, *P. trichocladum* and *T. laxum* as compared to *P. maximum* respectively (Table 41). Although *P. purpureum* was ranked the first and *T. laxum* the second in high milk yield criterion, the magnitude between the two species was not statistically significant ($P > 0.05$).

Table 41. Parameter estimates of animal preferences and high milk yield criteria with some grass forages used in smallholder farms of Turiani

Criteria of quality	Grass species	Coefficient	Odds ratio	Z value	Pr > Z value
Animal preferences	<i>P. purpureum</i>	-0.6464	0.5239	-1.57	0.1173
	<i>T. laxum</i>	0.7522	2.1217	1.83	0.0669
	<i>R. cochinchinensis</i>	4.0025	54.7348	10.01	<0.0001
	<i>P. trichocladum</i>	2.1309	8.4224	6.11	<0.0009
	<i>Cynodon</i> spp	2.3786	10.7898	7.58	<0.0001
	<i>Digitaria</i> spp	2.3560	0.4244	5.40	<0.0001
	<i>P. maximum</i>	.	.	.	.
High milk yield	<i>P. purpureum</i>	-0.1576	0.8542	-0.66	0.5094
	<i>T. laxum</i>	0.1536	1.1660	0.33	0.7407
	<i>R. cochinchinensis</i>	3.9499	51.9302	11.86	<0.0001
	<i>P. trichocladum</i>	2.3632	10.6249	8.17	<0.0001
	<i>Cynodon</i> spp	2.5912	13.3458	8.14	<0.0001
	<i>Digitaria</i> spp	2.9201	18.5431	6.36	<0.0001
	<i>P. maximum</i>	.	.	.	.

The odds ratio of stomach fill decreased to 83.83% with *P. purpureum* but increased to 11889.02%, 5792.22%, 3079.34% and 2842.87% with *R. cochinchinensis*, *Digitaria* spp, *P. trichocladum* and *Cynodon* spp respectively when all species were compared with *P. maximum* (Table 42). This indicated that *P. purpureum* was ranked the first and *T. laxum* ranked the second while *P. Trichocladum* and *Cynodon* spp ranked the last but one and the last respectively when the seven species were compared on how fast they could induce fast stomach fill.

The stomach fill criterion used in this context is what Stensig *et al.* (1994) considered as rumen fill, which is mainly accounted for based on NDF (fibre) or DM values (Stensig *et al.*, 1994; Madsen *et al.*, 1994). On their own merit, however, NDF values recorded (section 4.5) were high for all the grasses. On the other hand, stomach fill also depend on DM as fed that could also vary for forages collected on daily basis or those grazed *in situ* (Vollborn, 1998). Low DM of forages at feeding has influences on preference and intake (Vollborn, 1998). Crowder and Chheda (1982) also noted that after obtaining a reticulo-rumen fill, cattle stand or lie, before re-swallowing. Such behavioural observations of eating that include rumination (chewing the cud) were similar to farmers' views in the SPD as far as stomach fill criterion was concerned.

Farmers' consideration of the availability of various grass species indicated that *R. cochinchinensis*, *P. purpureum* and *P. trichocladum* were easily obtained given the fact that their respective odds ratio compared to *P. maximum* were 101.07%,

196.91% and 996.32% (Table 42). *T. laxum* was considered the least as far as availability was concerned.

Table 42. Parameter estimates of fast stomach fill and availability for different grass forages used in smallholder farms of Turiani

Criteria of quality	Grass species	Coefficient	Odds ratio	Z value	Pr > Z value
Stomach fill	<i>P. purpureum</i>	-0.1764	0.8383	-0.61	0.5411
	<i>T. laxum</i>	1.4831	4.4066	2.95	0.0032
	<i>R. cochinchinensis</i>	4.7782	118.8902	11.06	<0.0001
	<i>P. trichocladum</i>	3.4273	30.7934	8.72	<0.0001
	<i>Cynodon</i> spp	3.3474	28.4287	7.82	<0.0001
	<i>Digitaria</i> spp	4.0591	57.9222	7.56	<0.0001
	<i>P. maximum</i>	.	.	.	.
Availability	<i>P. purpureum</i>	0.6776	1.9691	2.13	0.0329
	<i>T. laxum</i>	3.4248	30.7165	9.56	<0.0001
	<i>R. cochinchinensis</i>	3.6852	1.0107	11.21	<0.0001
	<i>P. trichocladum</i>	2.2989	9.9632	7.05	<0.0001
	<i>Cynodon</i> spp	2.6771	14.5429	8.56	<0.0001
	<i>Digitaria</i> spp	3.1278	22.8237	8.43	<0.0001
	<i>P. maximum</i>	.	.	.	.

Animal forage preferences and availability of forages as criteria for quality were indications of farmers' understanding that some of the purposes of cattle keeping could be met if the available feeds were acceptable to animals and quantitatively consumed. This also included their interest in animal welfare reflected through their concerns on stomach fill (animal satisfaction), health and general conditions of their cows when they consider the type of feeds to offer. The amount of milk produced and its associated qualities were also based on both the household daily needs and that of the local community. This was equally true with other livestock systems including pastoral and agropastoral societies (Maeda-Machang'u *et al.*, 2000).

Field observation in the SPD revealed that biophysical and socio-economic factors were important on the aspects of availability and utilization of different pasture species. For example, the large-scale agricultural operations by MSE had opened up irrigation canals for sugar plantations. Consequently, *P. purpureum*, *P. maximum* and other important grass species that were probably established in the 1970's to stabilize banks of the canals are abundant. Most of these grass species are dispersed from the original planted points and are growing wildly. Thus farmers had free access to these grass forages and were also not restricted to collect forages in fallow fields of MSE. In addition, the company made regular maintenance of corridors and firebreaks for its plantations. These operations may also have had spill over effects to the feed management of zero grazed cattle in such a way that it was considered more convenient for farmers (and hired labour) to cut and carry feed forages on bicycles to their zero grazed cattle (Plate 3). This explains why individual farmers put little or no effort in deliberate establishment of desirable forage species, and minimum or no concern in the management of natural pasture (Düvel, 1998). However, availability of different forages was influenced by other factors including soils and climate. The high rainfall, temperatures and humidity normally recorded in the area (Figure 9, Figure 10 and Figure 11) are favourable for the tillering ability of species such as *P. maximum* (Aganga and Tshwenyane, 2004).

Pennisetum purpureum was perceived not to be the cause of feeding disorders such as diarrhoea or bloat and high milk quality when compared to the other species. On the other hand, *R. cochinchinensis* was viewed as the worst of all the species with

odds ratios of 1549% and 4113.67% respectively in the two quality criteria (Table 43).

Table 43. Parameter estimates of absence of feeding disorders and high milk quality for some grass forages used in smallholder farms of Turiani

Criteria of quality	Grass species	Coefficient	Odds ratio	Z value	Pr > Z value
Absence of feeding disorders	<i>P. purpureum</i>	0.2218	1.2483	1.28	0.1996
	<i>T. laxum</i>	1.2073	3.3444	2.88	0.0039
	<i>R. cochinchinensis</i>	2.7402	15.4901	8.33	<0.0001
	<i>P. trichocladum</i>	1.3088	3.7017	5.47	<0.0001
	<i>Cynodon</i> spp	1.6465	5.1888	5.79	<0.0001
	<i>Digitaria</i> spp	1.7801	5.9304	4.88	<0.0001
	<i>P. maximum</i>	.	.	.	.
High milk quality	<i>P. purpureum</i>	0.4051	1.4995	1.82	0.0680
	<i>T. laxum</i>	1.3740	3.9511	4.56	<0.0001
	<i>R. cochinchinensis</i>	3.7169	41.1367	11.10	<0.0001
	<i>P. trichocladum</i>	1.6480	5.1966	7.72	<0.0001
	<i>Cynodon</i> spp	2.1549	8.6270	6.34	<0.0001
	<i>Digitaria</i> spp	2.3528	10.5150	5.13	<0.0001
	<i>P. maximum</i>	.	.	.	.

Farmers harvested *R. cochinchinensis* in its early stages of growth before it was too inconvenient to cut (itchy). At such harvesting stages, however, DM content was likely to be too low to lead to other undesirable effects to cattle such as bloat (McDonald *et al.*, 1998).

Farmers' perceptions on the long term effect of grass species like on the general healthy condition of cows was that *P. purpureum* ranked first, *T. laxum* second, *P. trichocladum* third and *R. cochinchinensis* was ranked lowest when considering *P.*

maximum as a reference grass forage. Their respective odds ratios were 103.09%, 414.37%, 642.31 and 5382.30 (Table 44). Similarly, it was reported that it was more inconvenient to harvest *R. cochinchinensis* compared to the rest of the grass species. The hairy-itchy surface of *R. cochinchinensis* and short growth heights and trailing habit of *P. trichocladum* caused inconvenience during the harvesting or handling of the species (Minson, 1990).

Table 44. Parameter estimates of healthy animals and convenience in harvesting for different grass forages used in smallholder farms of Turiani

Criteria of quality	Grass species	Coefficient	Odds ratio	Z value	Pr > Z value
Healthy animals	<i>P. purpureum</i>	0.0304	1.0309	0.15	0.8775
	<i>T. laxum</i>	1.4216	4.1437	2.90	0.0037
	<i>R. cochinchinensis</i>	3.9857	53.8230	12.09	<0.0001
	<i>P. trichocladum</i>	1.8599	6.4231	5.76	<0.0001
	<i>Cynodon</i> spp	2.2650	14.1540	5.44	<0.0001
	<i>Digitaria</i> spp	2.2803	9.7796	4.98	<0.0001
	<i>P. maximum</i>	.	.	.	.
Convenience in harvesting	<i>P. purpureum</i>	-0.0055	0.9945	-0.02	0.9818
	<i>T. laxum</i>	1.5013	4.4875	3.53	0.0004
	<i>R. cochinchinensis</i>	4.3897	80.6162	10.95	<0.0001
	<i>P. trichocladum</i>	2.2898	18.1378	6.41	<0.0001
	<i>Cynodon</i> spp	2.5247	12.4871	6.48	<0.0001
	<i>Digitaria</i> spp	2.8649	17.5473	6.74	<0.0001
	<i>P. maximum</i>	.	.	.	.

The convenience of forages at harvesting and transportation to the stall, or impact of the feeds on health both in a long and short term, indicated farmers' complex assessment of resources. Inconveniences that could delay the farmer to attend other

farm or off farm activities as well as effect of feeding that may lead to more economic or social burdens could be avoided through choices made for higher-ranking grass forages in the respective criteria. This demonstrated further that improving milk production, for example, through the use of better forages must also consider health or socio-economic welfare of both the animal and the farmer. These observations concurred with those of Gold and Rusten (1993) who argued that farmers' choices of fodder had to be borne in mind when researchers and extension agents sought to improve the quality of life at the farm level.

The criteria used by farmers in the evaluation of local grass forages were consistent with some information generated through informal surveys with farmer groups in the study area (Table 45) and corroborated by research elsewhere for some of the species (Wandera, 1996). For example, based on chemical composition, the higher sugar content in *P. purpureum* could render it to be more palatable to animals (FAO, 2004b). Similarly, Wandera (1996) reported that when different grass forages were arranged based on palatability the order was *Themeda triandra*, *Pennisetum clandestinum* (Kikuyu grass), *Hyperrhenia rufa*, *Pennisetum* spp., *Cynodon plectostachyum*, *Leptochloa obtusiflora*, *Chloris gayana* (Rhodes grass), *Paspalum dilatatum*, *Panicum trichocladum*, *Paspalum scrobiculetum*, *Brachiaria soluta* and *Eragrostis paniciformis* respectively. On the other hand, the growth habits of both *P. purpureum* and *P. maximum* associated with their being perennial rendered them to be more persistent and available over seasons compared to other species (Aganga and Tshwenyane, 2004; FAO, 2004b).

Table 45. Overall matrix ranking of grass forages based on criteria given as used by four farmer groups

Criteria	Forage species					
	<i>P. purpureum</i>	<i>P. maximum</i>	<i>R. cochin*</i>	<i>P. trichocladum</i>	<i>Cynodon</i> spp	<i>Digitaria</i> spp
Palatability	3	1	1	1	1	1
Stomach fill	10	7	6	2	2	2
Milk yield	6	3	3	1	1	1
Total	19	11	10	4	4	4
Rank	1	2	3	4	4	4

**Rottboellia cochinchinensis*

4.4.4.2 Factors influencing choices of grass forages

4.4.4.2.1 Relationships of criteria of quality description in grass forages

The relationship of each of the forage quality criterion and the other criteria is presented in Table 46. Farmers' perception of animal preferences for grass forages were related to perceptions on influence of forages on milk yield and stomach fill and this relationship was significant ($P < 0.001$). On the other hand, the perception on high milk yield was highly influenced ($P < 0.001$) by their perception on animal preferences, stomach fill and absence of feeding disorders. Farmers' views on high milk yield were significantly ($P < 0.01$) related to the quality of milk although availability, animal health and convenience in harvesting did not show any significant ($P > 0.05$) effect on high milk yield. The results on the relationship of availability and other criteria showed that it was significantly ($P < 0.001$) related with stomach fill and absence of feeding disorders ($P < 0.01$) but not with the other criteria.

Table 46. Statistics on GEE analysis on relationship between criteria for grass forage qualities

Response (y)	Determinant (X1....Xn)	Chi square	Pr Chi square
Preference	High milk yield	53.71	<0.0001
	Fast Stomach fill	18.54	0.0003
	Availability	2.41	0.4915
	No feeding disorders	2.58	0.4617
	High milk quality	4.75	0.1909
	Healthy animal	5.83	0.1203
	Easy to harvest	3.67	0.2994
High milk yield	Preference	59.20	<0.0001
	Fast Stomach fill	69.30	<0.0001
	Availability	1.06	0.7859
	No feeding disorders	36.24	<0.0001
	High milk quality	15.60	0.0014
	Healthy animal	6.92	0.0744
	Easy to harvest	6.21	0.1016
Availability	Preference	6.45	0.0916
	High milk yield	5.67	0.1287
	Fast Stomach fill	36.15	<0.0001
	No feeding disorders	12.35	0.0063
	High milk quality	6.83	0.0774
	Healthy animal	2.28	0.5168
	Easy to harvest	5.86	0.1188

Table 46. continued

Response (y)	Determinant (X1....Xn)	Chi square	Pr Chi square
No feeding disorders	Preference	24.14	<0.0001
	High milk yield	2.86	0.4139
	Fast Stomach fill	3.62	0.3059
	Availability	11.25	0.0104
	High milk quality	13.85	0.0031
	Healthy animal	8.84	0.0315
	Easy to harvest	30.19	<0.0001
High milk quality	Preference	0.83	0.8430
	High milk yield	22.63	<0.0001
	Fast Stomach fill	8.49	0.0370
	Availability	12.02	0.0073
	No feeding disorders	17.16	0.0007
	Healthy animal	22.46	<0.0001
	Easy to harvest	16.18	0.0010
Healthy animal	Preference	3.31	0.3458
	High milk yield	9.01	0.0291
	Fast Stomach fill	0.09	0.9929
	Availability	4.17	0.2438
	No feeding disorders	5.62	0.1315
	High milk quality	25.30	<0.0001
	Easy to harvest	31.67	<0.0001

Farmers' perception on absence of feeding disorders was significantly ($P < 0.001$) related to animal preferences and convenience in harvesting the respective forages. This was also significantly related to availability and quality of milk produced ($P < 0.01$) and the general health status of the animal ($P < 0.05$). The perception of effect of grass forages on the quality of milk produced was not significantly ($P > 0.05$)

related to animal preferences. However, other criteria of forage quality significantly influenced the milk quality criterion at different levels especially on the quantity of milk produced and the health condition both on a short and long run ($P < 0.001$). Moreover, it was noted that the relationship of health performance and the rest of the quality criteria was highly significant ($P < 0.001$) with both the quality of milk and convenience in harvesting.

Consideration of farmers' views about the forage quality and the interrelationship of one set of views over the rest was an indication of how a farmer could interpret the situation amid other pressing factors within the farm or enterprise. This was because in any farm operations such as dairy cattle management, the farmer is confronted with other factors that either directly or indirectly related to the specific activity. Local interpretations of the situation, therefore, played a key role in the management and utilization of the resources in order to meet local needs although this could equally be shaped by new (exogenous) knowledge or information. It was probably this that made Senkondo (2000) to argue that mental interpretation of the physical farm situation could change with time or location. Hence, it is possible that local interpretations specific to Turiani could be applicable to other farming systems with similar conditions.

Although smallholder dairy farmers were mostly interested in quantity and quality of milk produced, animal welfare and forage availability were among other factors considered. Farmers were also concerned with the use of feeds that not only ensured good health in a short and long run but also those which were conveniently

harvested. These observations suggest further that any external effort to promote indigenous or exogenous forage species must have sustainable effects on social and economic spheres of smallholder farmers. Nevertheless, the goals of the farm operations and animal-environmental requirements may dictate what the farmer would get and what he/she has to do in order to realize the benefits of the dairy enterprise. The multi-objective nature in smallholder operations, for example, may call for integrating LK in livestock health management strategies as observed by Gwakisa *et al.* (2002). The authors demonstrated that combined use of local herbs (e.g. *Tephrosia vogelii*) and commercial acaricides would be more effective in the control of tick borne diseases than the use of either alone.

4.4.4.2.2 Legumes and forbs

Logistic regressions analyses of farmers' perceptions of the quality of legumes and forbs indicated that *M. pruriens* was the legume most preferred by cattle followed by *V. pubescens*, *I. aquatica* and *C. africana* in that descending order. The odds ratios of preference for these forages obtained with reference to *M. atropurpureum* were 143.56%, 218.23%, 307.41% and 595.06% respectively (Table 47). The rank order of the influence on high milk yield of legumes and forbs followed almost a similar trend with *V. pubescens* and *M. pruriens* ranked the highest and lowest in which the odds ratios were 144.54% and 1246.09% respectively

The odds ratio of stomach fill and availability with the different legumes and forbs is shown in Table 48. The odds ratio of stomach fill with *I. aquatica*, *C. africana*, *V.*

pubescens and *M. purpurians* all compared with *M. atropurpureum* were 29.61%, 82.90%, 190.22% and 201.68% respectively indicating the rank in stomach fill in the respective decreasing order.

The odds ratio of availability decreased with *C. africana* but increased with *I. aquatica*, *V. pubescens* and *M. pruriens* when the respective species were compared with *M. atropurpureum*. These were 98.26%, 167.65%, 228.51% and 486.32% for *C. africana*, *I. aquatica*, *V. pubescens* and *M. pruriens* respectively. In other words, *C. africana* was the most readily available and *M. pruriens* the least species.

Table 47. Parameter estimates of preference and high milk yield for different forage legumes and forbs used in smallholder farms of Turiani

Criteria of quality	Grass species	Coefficient	Odds ratio	Z value	Pr > Z value
Preferences	<i>V. pubescens</i>	0.7804	2.1823	2.54	0.0111
	<i>I. aquatica</i>	1.1230	3.0741	3.48	0.0005
	<i>C. africana</i>	1.7835	5.9506	5.76	<0.0001
	<i>M. pruriens</i>	0.3616	1.4356	6.43	<0.0001
	<i>M. atropurpureum</i>	.	.	.	.
High milk yield	<i>V. pubescens</i>	0.3684	1.4454	1.89	0.0583
	<i>I. aquatica</i>	1.1795	3.2527	3.99	<0.0001
	<i>C. africana</i>	1.6446	5.1789	6.34	<0.0001
	<i>M. pruriens</i>	2.5226	12.4609	7.42	<0.0001
	<i>M. atropurpureum</i>	.	.	.	.

Table 48. Parameter estimates of fast stomach fill and availability for different forage legumes and forbs used in smallholder farms of Turiani

Criteria of quality	Grass species	Coefficient	Odds ratio	Z value	Pr > Z value
Stomach fill	<i>V. pubescens</i>	0.6430	1.9022	2.91	0.0036
	<i>I. aquatica</i>	-1.2170	0.2961	-4.17	<0.0001
	<i>C. africana</i>	-0.1875	0.8290	-0.65	0.5167
	<i>M. pruriens</i>	0.7015	2.0168	3.16	0.0016
	<i>M. atropurpureum</i>	.	.	.	.
Availability	<i>V. pubescens</i>	0.8264	2.2851	3.28	0.0010
	<i>I. aquatica</i>	0.5167	1.6765	1.85	0.0644
	<i>C. africana</i>	-0.0175	0.9826	-0.07	0.9474
	<i>M. pruriens</i>	1.5817	4.8632	5.04	<0.0001
	<i>M. atropurpureum</i>	.	.	.	.

The odds ratio of absence of feeding disorders with different forage legumes and forbs found in Turiani is depicted in Table 49. The odds of absence of feeding disorders with *I. aquatica*, *V. pubescens*, *C. africana* and *M. purpuriens* increased respectively to 127.20%, 138.67%, 191.51% and 193.52% when the respective species were compared with *M. atropurpureum*. The ranking of the legume and forbs on the basis of high milk quality in descending order were *V. pubescens*, *I. aquatica* and *C. africana*.

As with grasses, legumes and forbs were evaluated based on the multiple criteria, which also signified important associative effects that the feeds may have, or at least what the farmers felt would happen. This was demonstrated with responses for the two forbs, *I. aquatica* and *C. africana* where it was noted that *I. aquatica* was ranked the first and *C. africana* the second based on fast stomach fill. However, it was felt that there was more risk of diarrhoea or bloat upon feeding cattle with *I. aquatica*.

Table 49. Parameter estimates of absence of feeding disorders and high milk quality for forage legumes/forbs used in smallholder farms of Turiani

Criteria of quality	Grass species	Coefficient	Odds ratio	Z value	Pr > Z value
Absence of feeding disorders	<i>V. pubescens</i>	0.3269	1.3867	2.27	0.0234
	<i>I. aquatica</i>	0.2406	1.2720	3.19	0.0014
	<i>C. africana</i>	0.6498	1.9151	3.01	0.0026
	<i>M. pruriens</i>	0.6602	1.9352	3.39	0.0007
	<i>M. atropurpureum</i>	.	.	.	.
High milk quality	<i>V. pubescens</i>	11.1054	66529.4509	11.00	<0.0001
	<i>I. aquatica</i>	12.8527	381818.2542	27.90	<0.0001
	<i>C. africana</i>	13.3845	649852.0496	37.26	<0.0001
	<i>M. pruriens</i>	13.8554	1040695.7106	36.15	<0.0001
	<i>M. atropurpureum</i>	.	.	.	.

Such choices of forages based on multiple criteria were an indication of the rigorous evaluation process that a new technology undergoes in smallholder communities before it is accepted or rejected. Practically, this suggested that needs and aspiration of smallholder farmers ought to be taken aboard in promoting the use of indigenous or exogenous forage species. Different on farm research have benefited through interactive activities of researchers and farmers as reported in respect to the establishments and management of the multipurpose trees in different parts of tropical Africa (Franzel, 1999) and Asia (Walker *et al*, 1999). Similar findings were reported from Tororo district in Uganda where legume and shrub species were being evaluated based on farmers' evaluation criteria. The ranking of the legume and shrub species was (from first to last) *Mucuna*, *Canavalia*, *Crotalaria*, *Tithonia*, *Tephrosia* and *Lablab* (Douthwaite *et al.*, 2003).

Meanwhile, it was noted from the study that ranking of forages with respect to local quality criteria was neither gender biased nor influenced by the number of cows kept by individual farmers (page 100). This is contrary to some other studies where men and women had different views on local resources as a result of the different household and community roles the two gender groups do play (Laswai *et al.*, 1999; Kajembe *et al.*, 2000b). However, the specific focus of the present study (forage quality description for forages used for cattle) and the closeness that each gender group may attach to cattle kept under the zero grazing system may be reasons for deviations of observations in the present and other previous studies. These findings, therefore, could have implications on matters associated with rural development policies at local, national or regional and international levels, especially when the focus is on issues related to LKS. In other words, in situations whereby local farmers are involved in rural development issues, it may not be necessary to discriminate between different gender groups or wealth categories. Instead, when initiating a project such as the one involving the introduction of new pasture species (or developing local forage materials) in smallholder dairy production systems, it is important to involve all gender groups and different wealthy categories (as could be described locally). Observations made in Zambia (Phiri *et al.*, 2004) revealed that gender and differences on wealth categories based on farmers' perspectives (wealth ranking criterion) did not limit the adoption of the tree planting technology.

4.5 Comparison between nutritive value of forages based on LK and that in feed tables and feeding systems

4.5.1 Chemical composition

Mean (\pm sd) CP content of *P. purpureum* ($11.36 \pm 2.21\%$) was higher than that of *P. maximum*, *R. cochinchinensis* and *P. trichocladum* (Table 50(a)). The minimum CP content of 4.33% was obtained from *P. maximum*. The ADF content of the grasses harvested for feeding varied among forage species. Maximum and minimum ADF content were 65.31% and 39.59% for *P. purpureum*, 57.50% and 37.99 for *P. maximum*, 50.80% and 31.83 for *R. cochinchinensis* and 65.26% and 42.32 for *P. trichocladum*. On the other hand, mean NDF for *P. purpureum*, *P. maximum*, *R. cochinchinensis* and *P. trichocladum* were 69.67%, 71.26%, 72.22% and 68.91% respectively. The maximum and minimum IVDMD were 56.15% and 32.95% for *P. purpureum*, 54.20% and 32.46% for *P. maximum*, 47.93 and 41.55% for *R. cochinchinensis* and 51.48% and 37.38% for *P. trichocladum*. *In vitro* OMD of grass forages also varied from one species to another where the mean value (\pm sd) for *R. cochinchinensis* ($49.16 \pm 4.08\%$) was higher compared to $42.72 \pm 2.04\%$ for *P. purpureum*, 43.43 ± 6.14 for *P. maximum* and 44.41 ± 3.76 for *P. trichocladum* respectively. The ME content also varied from 4.12 to 7.53 MJ/kgDM for *P. purpureum*, 4.05 to 7.25 MJ/kgDM for *P. maximum*, 5.39 to 6.33 MJ/kgDM for *R. cochinchinensis* and 4.70 to 6.85 MJ/kgDM for *P. trichocladum*. Table 50(b) shows composition of some of the common legumes and forbs used in stall-feed cattle in the SPD.

Table 50(a). Chemical composition of common grass forages used in smallholder dairy farms in Turiani division

Parameter		Grass species			
		<i>P. purpureum</i>	<i>P. maximum</i>	<i>Rottboelia</i>	<i>P. trichocladum</i>
DM	Mean	92.01	92.21	91.27	91.87
	SD	0.84	1.05	0.65	0.82
	Max	93.05	93.25	92.17	93.40
	Min	90.70	90.30	90.70	90.70
as % DM					
Ash	Mean	14.15	11.45	12.42	10.70
	SD	3.00	2.85	0.19	1.34
	Max	19.43	17.26	12.65	13.81
	Min	8.17	8.95	12.18	9.09
CP	Mean	11.37	8.63	7.96	8.27
	SD	2.21	3.32	0.48	1.77
	Max	17.14	16.37	8.49	12.03
	Min	7.16	4.33	7.32	5.14
ADF	Mean	48.89	50.25	44.97	51.63
	SD	5.58	4.86	8.95	6.79
	Max	65.31	57.50	50.80	65.26
	Min	39.59	37.99	31.83	42.32
NDF	Mean	69.67	71.26	72.22	68.91
	SD	5.68	3.47	2.71	4.41
	Max	79.93	77.96	75.19	75.27
	Min	50.50	64.11	69.07	60.02
IVDMD	Mean	41.09	41.30	43.65	42.72
	SD	5.74	5.81	2.90	3.85
	Max	56.15	54.20	47.93	51.48
	Min	32.95	32.46	41.55	37.38
IVOMD	Mean	42.72	43.43	49.16	44.41
	SD	2.04	6.14	4.08	3.76
	Max	57.43	54.57	52.63	50.35
	Min	52.06	33.58	43.40	37.87
ME (MJ/kgDM)					
	Mean	5.32	5.35	5.70	5.56
	SD	0.84	0.86	0.43	0.57
	Max	7.53	7.25	6.33	6.85
	Min	4.12	4.05	5.39	4.70

Table 50(b). Chemical composition of common forage legumes / forbs used in smallholder dairy farms in Turiani division

Parameter		Forage legumes / Forbs			
		<i>C. africana</i>	<i>M. atropurpur.</i>	<i>V. pubescens</i>	<i>I. aquatica</i>
DM %	Mean	90.51	91.80	91.93	91.04
	SD	1.30	1.33	0.40	0.26
	Max	91.90	93.58	92.40	91.41
	Min	89.00	89.59	91.70	90.81
(as % DM)					
Ash	Mean	13.87	10.42	7.18	15.96
	SD	5.22	2.70	0.16	2.37
	Max	10.09	15.64	7.36	18.26
	Min	20.97	7.55	7.09	12.89
CP	Mean	11.62	16.62	12.88	19.91
	SD	4.95	2.93	1.67	5.82
	Max	19.91	22.53	13.85	28.43
	Min	7.30	12.39	10.95	15.57
ADF	Mean	49.61	47.82	44.43	43.29
	SD	9.51	6.23	1.77	11.81
	Max	63.89	59.10	46.48	50.40
	Min	39.89	38.49	43.41	25.68
NDF	Mean	66.32	58.03	57.45	45.97
	SD	3.60	9.66	2.78	11.40
	Max	70.88	69.33	60.66	54.63
	Min	60.87	37.90	55.84	30.00
IVDMD	Mean	53.65	50.53	29.64	65.04
	SD	7.38	8.73	8.77	5.42
	Max	63.56	63.70	39.77	72.98
	Min	43.01	39.23	24.58	60.74
IVOMD	Mean	52.87	50.23	32.12	61.85
	SD	7.35	7.92	5.51	5.63
	Max	61.27	61.39	38.48	69.89
	Min	41.42	42.08	28.94	56.73
ME (MJ/kgDM)					
	Mean	7.17	6.71	3.64	8.84
	SD	1.09	1.28	1.29	0.80
	Max	8.62	8.64	5.13	10.01
	Min	5.60	5.05	2.89	8.21

The CP content of legumes and forbs were as low as 7.30% in *C. africana* to as high as 28.43% in *I. aquatica* with mean (\pm sd) values of $11.62\pm 4.95\%$, $16.62\pm 2.93\%$, $12.88\pm 1.67\%$ and $19.91\pm 5.82\%$ for *C. africana*, *M. atropurpureum*, *V. pubescens* and *I. aquatica* respectively. The maximum and minimum ADF contents of *C. africana*, *M. atropurpureum*, *V. pubescens* and *I. aquatica* were 63.89% and 39.89%; 59.10% and 38.49%; 46.48% and 43.41% and 50.40% and 25.68 respectively. The NDF content of *C. africana*, *M. atropurpureum*, *V. pubescens* and *I. aquatica* was 66.32%, 58.03%, 57.45% and 45.97% respectively. The respective maximum and minimum IVDMD of *C. africana*, *M. atropurpureum*, *V. pubescens* and *I. aquatica* were 63.56% and 43.01%; 63.70% and 39.23%; 39.77% and 24.58% and 72.98% and 60.74%.

The ME of legumes and forbs varied from 5.60 to 8.62 MJ/kgDM for *C. africana*, 5.05 to 8.64 MJ/kgDM for *M. atropurpureum*, and 8.21 to 10.01 MJ/kgDM for *I. aquatica*. *Vigna pubescens* had the lowest ME content (mean \pm sd, 3.64 ± 1.29 MJ/kgDM).

The average CP content for all grasses were within the minimum threshold level of 6.5 to 7.5% that is needed for microbial activities in the rumen (Van Soest, 1994) and as expected, the CP values of legumes and forbs were higher than those of grass forages. Tropical grasses follow the C4 pattern as opposed to the C3 of the temperate counterparts and legumes thus the grasses had relatively more ADF and NDF content than legumes and forbs (Minson, 1990). The low *in vitro* DM and OM digestibility may be associated with both the low CP and high ADF and NDF since legumes and

forbs with higher CP content had higher *in vitro* DM and OM digestibility than grasses with low CP content. Michalet-Doreau and Ould-Bah (1992) reported that digestibility was influenced by the chemical composition of the feedstuff especially protein. Aganga and Tshwenyane (2004) reported a decrease in the digestibility of *P. maximum* cultivars that was also associated with fertility of soils and maturity stages of the grasses. Martha *et al.* (2004) also reported that the increase in N and therefore CP of pastures led to increase in the digestibility of elephant grass.

The compositions of most of the evaluated forages were within the ranges reported by other researchers (Kavana *et al.*, 1999; Aganga and Tshwenyane, 2004). However, *in vitro* DMD and OMD were lower compared to values of up to 52 to 57% for similar grass species found in the same area (Temi, 1999) although values ranging from 45 to 85% have been reported in tropical grass and legume species (Van Soest, 1994). But the unexpected low IVDMD and IVOMD for most grass species and legumes such as *V. pubescens* in the study area could, however, be due to analytical discrepancies. Shortcomings of the *in vitro* techniques such as variation in microbial populations, sample size, medium during incubation and procedures, duration of fermentation, dilution rate and quality of rumen liquor (Veresegyházy *et al.*, 1989) may well have contributed to the variations observed in the present study analyses. Similarly, the variation in ME was not only due to the variation in season, place and stages of maturity but also due to variation in the *in vitro* DMD and OMD from which ME was derived. Although the minimum ME content was lower than other reported values (Aminah and Chen, 1991), the maximum were within these ranges (6.85 – 7.53 MJ ME/kgDM). Smallholder dairy farmers in the SPD farming

system collect forages on daily basis. It is therefore likely that the compositions of the forages varied widely because of the variations in locations (sources) and phenological characteristics of the feeds. The sources where forages were obtained include farm boundaries or fields prior and during weeding. The communal flood plains, riverbeds or paths and roadsides were also sources of forages where farmers harvested forages with varying stages of maturity and/or from different microclimates. From participant observations and reports in the SPD, it was noted that there were instances whereby spot application of commercial fertilizers was done especially in sugarcane production. Thus, forages from such fertilized sources were likely to have varying composition compared to those obtained from unfertilized sources (Relling *et al.*, 2001).

In most cases, smallholder farmers in the SPD and similar production systems do not rely on composition to judge quality of grasses or legumes as it may be with analytical chemists and nutritionists (Schneider and Flatt, 1975) or other farmers in high input-high output systems (Spedding, 1995). However, their visual observations and experiences in feeding and handling of feeds lead them to keep an eye on forages that they consider to be of higher qualities than others. Participant observation and interview techniques showed that whenever possible, farmers tend to avoid the very mature forages because they are coarse or stemy, therefore may not be preferred by calves or other classes of cattle. From the analytical point of view, very mature materials contain higher fibres (e.g. NDF) than those at younger stages of maturity (Relling *et al.*, 2001). Low palatability however, is reflected from high DM at feeding and high fibre that increase rumen fill and reduce intake (Stensig *et al.*,

1994). On the other hand, ultimate production targets met through farmers' choices of legumes and grass forages of the favoured maturity stages are inevitably due to high nutritive values such as high IVDMD, IVOMD and *in vivo* digestibilities of DM, CP and other nutrients (Schneider and Flatt, 1975; McDonald *et al.*, 1998).

4.5.2 Rumen degradability of dry matter

The DM degradability characteristics of individual forages and that of the forage mixture used in the growth study are presented in Table 51(a) while Table 51(b) shows the degradability characteristics of the concentrates. Appendices 4, 5 and 6 show composition of grass forages used in the study and the fitted values for DM degradability of forages and concentrate feeds respectively. The potentially degradable fraction (defined by $a+b$) for *P. maximum* and *P. trichocladum* as well as that of the 1:5 mixture of the (i.e. *P. trichocladum*: *P. maximum*) species were 65.54%, 59.76% and 61.09% respectively and these were not significantly different from each other ($P > 0.01$). The assumed *in vivo* digestibility (DM degradability at 48 hours) varied from 43.86% for *P. trichocladum* to 44.18% and 46.38% for *P. maximum* and the 1:5 grass mixtures respectively and these characteristics did not differ significantly ($P > 0.01$) from each other. The DM degradability characteristics of the concentrate mixture used were superior to that of the forages as indicated by DM disappearance shown in Figure 18 and Figure 19 for individual ingredients and mixtures of forages and concentrates respectively.

Table 51(a). Least square means of DM degradability constants of individual and mixed forages used for growth study

Forage	%			48 hours Dg	%h ⁻¹	
	a	b	a + b		c	ED
I	12.55 ^a	52.99 ^a	65.54 ^a	44.18 ^a	0.021 ^a	38.27 ^a
II	12.27 ^a	48.82 ^a	61.09 ^a	46.38 ^a	0.029 ^a	39.53 ^a
III	11.61 ^a	48.15 ^a	59.76 ^a	43.86 ^a	0.024 ^a	37.30 ^a
SEM	0.79	2.06	2.58	3.04	0.60	1.82
SL	NS	NS	NS	NS	NS	NS

^aMeans within the same column with the same superscript do not differ significantly (P>0.01);

SEM = Standard error of mean

SL = Significance level

NS = Not significant

I = *Panicum maximum*

II = *Panicum maximum* + *P. trichocladum* (in 5:1 ratio)

III = *P. trichocladum*

Dg = degradability

ED = effective degradability (0.02h⁻¹)

Table 51(b). Least square means of DM degradability constants of ingredients and concentrate mixture for preference and growth studies

Feed	%			48 hr Dg	%h ⁻¹	
	a	b	a + b		c	ED
Maize bran	37.56 ^a	54.23 ^a	91.79 ^a	88.87 ^a	0.069 ^b	79.03 ^a
SSC	24.48 ^a	38.84 ^b	63.32 ^c	63.32 ^c	0.221 ^a	59.90 ^c
CSC	29.63 ^a	54.72 ^a	84.38 ^a	73.01 ^b	0.045 ^b	64.47 ^b
GSLM	36.42 ^a	41.86 ^b	78.29 ^b	76.87 ^b	0.073 ^b	69.20 ^b
Mixture	27.56 ^a	51.64 ^a	79.19 ^{ab}	77.62 ^b	0.073 ^b	68.13 ^b
SEM	3.25	3.34	2.68	2.00	0.02	1.46
SL	**	**	**	**	**	**

^{a,b,c}Means within the same column with the same superscript do not differ significantly at (P > 0.01);

SEM = Standard error of mean

SL = Significance level

** Significant at 0.01

SSC = Sunflower seed cake

CSC = Cotton seed cake

GSLM = *Gliricidia sepium* leaf meal

Mixture = Concentrate mixture of SSC, CSC and GSLM

Dg = degradability

ED = effective degradability (0.02h⁻¹)

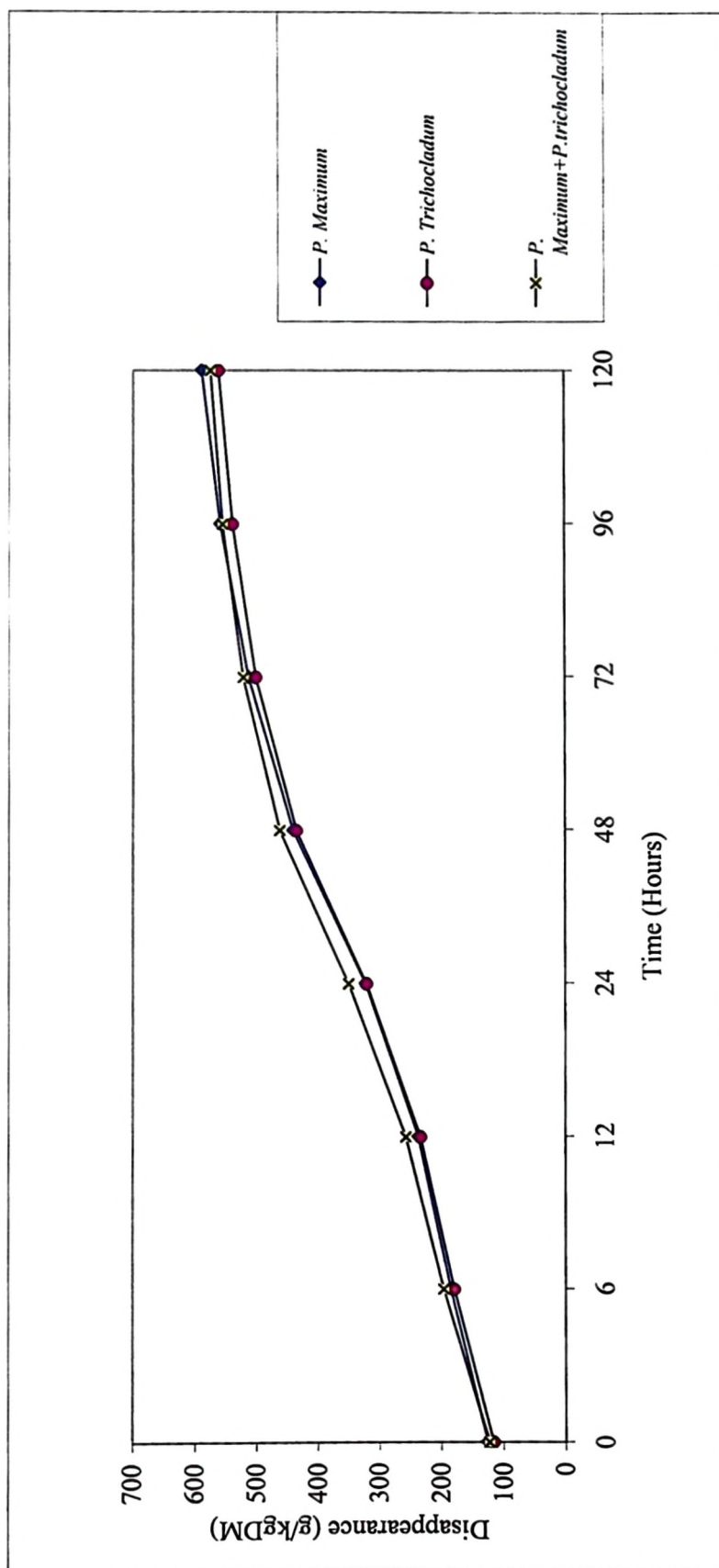


Figure 18. Rumen DM degradability of forages used in the growth experiment

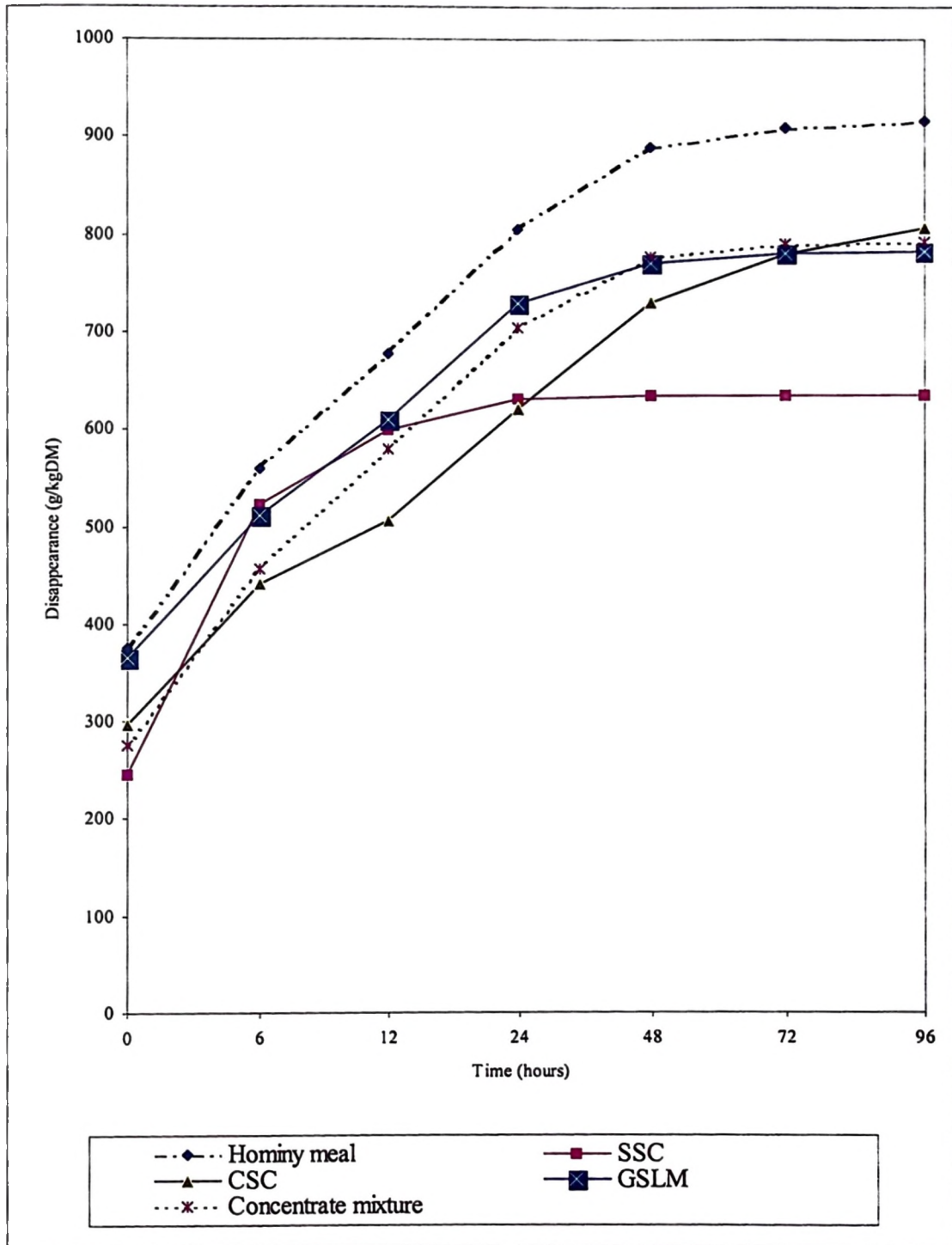


Figure 19. Rumen DM degradability of individual ingredients and the concentrate mixture

4.5.3 Animal experimentation in relation to local description of forage quality

4.5.3.1 Assessment of preferences of grass forages by cross-bred calves

4.5.3.1.1 Composition of forages used in the preference study

Composition and nutritive value of forages used in the assessment of forage preferences is shown in Table 52. Mean dry matter (DM) content on as fed basis for the grass materials offered were 25.81 ± 1.98 , 32.54 ± 1.27 , 18.88 ± 1.75 and 23.83 ± 2.29 g/100gDM for T1, T2, T3 and T4 respectively while M11, M12, M13 and M14 had DM content of 30.67 ± 0.41 ; 27.46 ± 0.22 ; 24.74 ± 0.45 and 27.85 ± 0.82 g/100gDM respectively. There was a wide variation in CP composition with minimum and maximum CP content ranging from 6.7 to 12.17g/100g DM. The mean CP content of individual grasses varied from 7.83 ± 0.60 to 9.65 ± 0.80 g/100gDM (Table 52), being slightly better than the minimum threshold level of 6.5 - 7g/100g DM required for microbial activity initiation in the rumen (Van Soest, 1994). Mean ADF and NDF varied from 46.54 ± 1.64 and 84.25 ± 2.53 (for T4) to 49.82 ± 1.19 and 88.28 ± 1.19 (for T2) respectively. The composition of grasses used in the preference and growth studies (Appendix 4) was found in similar areas where other samples (Table 50 (a)) were obtained. Therefore the factors influencing composition such as soils, weather and the general management practices affected them all (section 4.5.1; Leng, 1997). The chemical compositions of these tropical pasture species were within the range of values reported by Minson (1990).

Table 52. Mean composition and nutritive value of grass species used in the preference study

Species Name	DM ¹	g per 100g DM							Energy (MJ ME/kgDM)
		DM	Ash	CP	ADF	NDF	IVDMD	IVOMD	
<i>P. maximum</i>	25.81 (1.98)	92.61 (0.31)	11.23 (1.40)	7.83 (0.60)	48.22 (0.75)	70.07 (0.41)	42.74 (0.91)	47.63 (5.53)	5.57 (0.13)
<i>P. trichocladium</i>	32.54 (1.27)	92.33 (0.34)	9.58 (0.56)	9.65 (0.80)	49.82 (1.19)	69.25 (0.38)	39.10 (1.33)	40.36 (1.41)	5.03 (0.20)
<i>P. purpureum</i>	18.88 (1.75)	91.95 (0.20)	10.68 (0.14)	9.62 (1.09)	46.73 (2.67)	69.47 (0.33)	41.65 (0.97)	49.19 (1.91)	5.40 (0.14)
<i>R. cochinchinensis</i>	23.83 (2.29)	92.00 (0.63)	12.18 (0.62)	9.61 (0.81)	46.54 (1.64)	69.50 (0.23)	43.22 (1.65)	48.63 (2.25)	5.63 (0.24)

¹DM as fed. This was 30.67 (0.41); 27.46 (0.22); 24.74 (0.45) and 27.85 (0.82) g/100g for M11, M12, M13 and M14 respectively where:

M11 = *P. maximum* + *P. trichocladium*;

M12 = *P. maximum* + *R. cochinchinensis*

M13 = *P. purpureum* + *R. cochinchinensis* and

M14 = *P. purpureum* + *P. trichocladium*

4.5.3.1.2 Experiment 4.1 Single forage presentations

Least square means of intake and feeding behaviour of calves on single forage species is shown in Table 53. Individual quantities of forages consumed and behaviour of calves during feeding are shown in Appendix 7. Analysis of variance results are shown in Appendix 11. The quantity of DM consumed for T3 of $235.76 \pm 10.27 \text{gDM}/15 \text{min}$ was significantly higher ($P < 0.05$) than that of the other three species offered singly. Although T2 was the least consumed ($140.46 \pm 10.27 \text{gDM}/15 \text{min}$) this amount was not significantly different ($P > 0.05$) from either T1 or T4.

Table 53. Least square means of quantities consumed and feeding behaviour by growing bull calves fed single forage species

	Treatment				SEM
	T1	T2	T3	T4	
Amount (gDM)					
Total intake (g/15 min)	146.77 ^b	140.46 ^b	235.76 ^a	171.55 ^b	10.27
Intake rate (g/min)	9.78 ^b	9.36 ^b	15.72 ^a	11.44 ^b	0.68
Intake rate (g/LW ^{0.75})	0.36 ^b	0.34 ^b	0.57 ^a	0.41 ^b	0.03
Bites					
Total (bites/15 min)	70.19 ^b	60.63 ^c	79.69 ^a	80.81 ^a	2.72
Bite rate (bites/min)	4.68 ^b	4.04 ^c	5.31 ^a	5.38 ^a	0.18
Bite mass (g/bite)	2.23 ^b	2.57 ^{ab}	3.11 ^a	2.14 ^b	0.22

T1 = *P. maximum*; T2 = *P. trichocladum*; T3 = *P. purpureum*; T4 = *R. cochinchinensis*. SEM = standard error of mean

^{a,b,c}Means within a row with different superscripts differ significantly ($P < 0.05$).

The intake rate of $15.72 \pm 0.68 \text{g/min}$ for T3 was equally the highest and significantly ($P < 0.05$) different from that of T1, T2 and T4. The bite rate of T2 ($4.04 \pm 0.18 \text{bites/min}$) was significantly lower ($P < 0.05$) than the rates for T1, T3 and T4 and consequently the lowest intake for T2. However, the bite mass for T2 ($2.57 \pm 0.22 \text{g/bite}$) was not statistically different ($P > 0.05$) from T4 that attained the highest intake level.

The relationship between chemical content of forage and intake of the single forage species is shown in Table 54. DM intake ($\text{g/kgLW}^{0.75}$) was negatively correlated with DM content ($r = 0.45$, $P < 0.001$). The correlation between DM intake and ME content was poor ($r = 0.13$) and not statistically significant ($P > 0.05$). Dry matter intake was positively correlated with bite mass and this relationship was strong ($r = 0.72$, $P < 0.001$). The relationship between DM intake ($\text{g/kgLW}^{0.75}$) and DM as fed (g/100g) (\pm standard error) was described by the equation (xiv):

$$\text{Intake (g/kgLW}^{0.75}\text{)} = 10.03(\pm 0.97) - 0.15(\pm 0.04) \text{ DM as fed (g/100g)}$$

($P = 0.0002$, $F = 15.4$, $R^2 = 0.20$) Equation (xiv).

Forage preference derived from intake rate indicated that growing calves preferred *P. purpureum* to the other three species used in this study. The low DM content of forages at the time of feeding could have influenced this observation. This is in agreement with findings of Gibb *et al.* (1998) and Vollborn (1998) that DM content and surface moisture content of grazed forages raise bite rates and bite mass on fresh weight basis although they are lowest on the basis of DM.

Table 54. Pearson correlation coefficients of chemical and nutritional values and palatability estimates of forages offered singly to bull calves

	ME	NDF	IVDMD	IVOMD	Intake ^a	BM ^b	IR ^c
DM	-0.47***	-0.11 ^{NS}	-0.47***	-0.37**	-0.45***	-0.08 ^{NS}	-0.28*
ME		0.26*	0.99***	0.64***	0.13 ^{NS}	-0.10 ^{NS}	0.08 ^{NS}
NDF			0.26*	0.11 ^{NS}	-0.13 ^{NS}	-0.22 ^{NS}	-0.17 ^{NS}
IVDMD				0.64***	0.14 ^{NS}	-0.09 ^{NS}	0.08 ^{NS}
IVOMD					0.08 ^{NS}	-0.23 ^{NS}	-0.01 ^{NS}
Intake ^a						0.72***	0.36**
BM ^b							0.18 ^{NS}

DM = Dry matter (as fed), g/100g; ME = Metabolizable energy, MJ ME/KgDM;

NDF = Neutral detergent fibre g/100g IVDMD = *In vitro* DM digestibility g/100g

IVOMD = *In vitro* organic matter digestibility g/100g; ^aIntake (g/kg LW^{0.75}); ^bBM = Bite mass, gDM/bite;

^cIR = Intake rate gDM/minute *** Significant at 0.001 level ** Significant at 0.01 level

* Significant at 0.05 level ^{NS} = Non significant

The findings are also consistent with farmers' arguments that *P. purpureum* could be consumed more because of higher water content than other species such as *P. trichocladum*. On the other hand, results in the present study were different from those of Dougherty *et al.* (1988) who demonstrated that when beef cattle grazed alfalfa of DM content of 160 - 280 g/kgDM the bite mass varied from 0.86 to 1.17 (gDM/bite). This was probably because the animals in this study were under zero grazing and were fed on grass forages with higher leaf: stem ratio than alfalfa.

However, the ME content may not have a direct influence on preference of tropical forages in a short term although both DM and ME have a significant contribution to total DM intake and overall performance of livestock on a long term. *P. purpureum* was, however, reported to have a relatively higher sugar content (FAO, 2004b), something that may account for its higher consumption compared to other forages used in the present study. This could also be related to the argument of Mayland *et al.* (2000) who indicated that non-structural carbohydrates that are readily fermentable (such as sucrose) could play a role in diet preferences for hungry animals.

4.5.3.1.3 Experiment 4.2 Mixed forage presentations

Least square means of intake and feeding behaviour of calves on mixed forages is shown in Table 55. Individual quantities of materials consumed and feeding behaviour of calves during the study are shown in Appendix 8. Analysis of variance results are indicated in Appendix 12 in which least square means (\pm SEM) for intake

of mixed forage species ranged from 160.20 to 232.52g/15min. The intake rate of M14 (232.52±5.71g/15min) was significantly higher than that of M11 and M12 but not significantly ($P < 0.05$) different from that of M13. The bite rates for M11, M12, M13 and M14 were respectively 3.92, 5.17, 5.34 and 4.69 (±0.09). These were significantly ($P < 0.05$) different from each other. Generally, the higher intake rate of M13 and M14 (14.97 and 15.50 (±0.38)gDM/min) and subsequently high bite mass (2.85 - 3.34 (±0.08) gDM/bite) made the mixture containing *P. purpureum* to be the most preferred. On the other hand, there was a general observation of proportionate decrease in bite mass with an increase in bite rate particularly for grass species offered singly (Figure 20).

Table 55. Least square means of quantities consumed and feeding behaviours by growing bull calves fed mixed forage species

	Treatment				SEM
	M11	M12	M13	M14	
Amount (gDM)					
Total intake (g/15 min)	160.20 ^b	172.47 ^b	224.54 ^a	232.52 ^a	5.71
Intake rate (g/min)	10.68 ^b	11.50 ^b	14.97 ^a	15.50 ^a	0.38
Intake rate (g/LW ^{0.75})	5.84 ^b	6.29 ^b	8.21 ^a	8.49 ^a	0.21
Bites					
Total (bites/15 min)	58.75 ^d	77.63 ^b	80.06 ^a	70.31 ^c	1.36
Bite rate (bites/min)	3.92 ^d	5.17 ^b	5.34 ^a	4.69 ^c	0.09
Bite mass (g/bite)	2.76 ^b	2.26 ^c	2.85 ^b	3.34 ^a	0.08

^{a,b,c,d}Means within a row with different superscripts differ significantly ($P < 0.05$).

M11 = *P. maximum* + *P. trichocladum*; M12 = *P. maximum* + *R. cochinchinensis*

M13 = *P. purpureum* + *R. cochinchinensis*; M14 = *P. purpureum* + *P. trichocladum*

SEM = Standard error of mean

Intake rates observed in the present study represent some of the key factors in understanding palatability and voluntary feed intake. The high intake rate for any forage may have significant implication to a smallholder farmer who harvests forages from rangelands on a daily basis or a farmer planning to establish one or more pasture species from among the choices available. Alternatively, this implies associative effects on rumen (physical) fill, animal satisfaction and performance if the respective forage was supplied *ad libitum*. Unlike in studies where bite rates declined with increasing bite mass (Forbes, 1988) and where prehensile bite rate doubled when intake rate declined (Black and Kenney, 1984), such a direct relationship was not found in the present study (Figure 20). This relationship is probably due to the practice of harvesting the feeds daily, which is associated with the use of species with varying characteristics. Kenney and Black (1984) and De Rosa *et al.* (1997) also demonstrated that factors such as particle size, fibre content, phenological stage, grazing environments or animal body weight may influence intake. De Rosa *et al.* (1997) reported that in short-term trials intake rate was determined by bite mass and bite rate whereby these two variables depend on each other. However, Forbes (1988) maintained that bite mass (bite size) varies widely with type and stage of growth of forage under investigation including the differences in leaf: stem ratio. The leaf to stem ratio of the other three grass species used in the present study is higher at any stage of growth than of *P. trichocladum* (Crowder and Chheda, 1982; Minson, 1990).

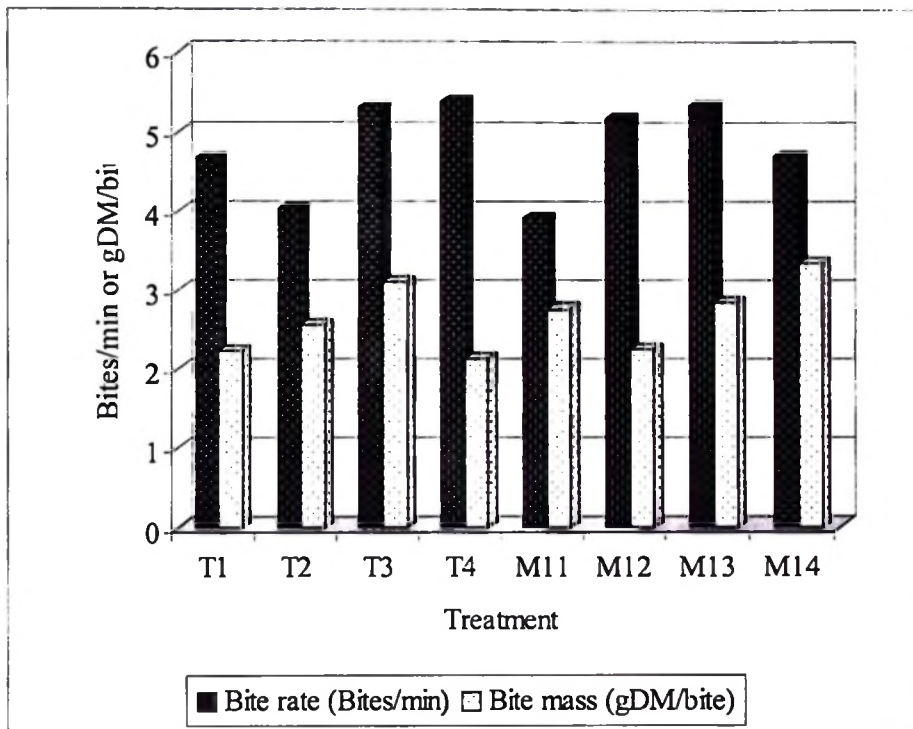


Figure 20. Comparison of forage preferences by calves: Relationship between bite rate and bite mass of single and mixed tropical grasses

Key:

T1 = *P. maximum*; T2 = *P. trichocladum*; T3 = *P. purpureum*; T4 = *R. cochinchinensis*. M11 = *P. maximum* + *P. trichocladum*; M12 = *P. maximum* + *R. cochinchinensis*
 M13 = *P. purpureum* + *R. cochinchinensis*; M14 = *P. purpureum* + *P. trichocladum*

The improvement (increase) on bite rate, intake rate as well as on bite mass was observed with grass species fed in mixtures compared to single species. Associative effects emanating from two individual forages could have influenced the trend of observed parameters with these mixed grasses. This is in agreement with findings of Bwire *et al.* (2003) who noted an increase in DM intake and milk yield when combining different grass species. In both single and mixed forage cases other factors such as physical feel, taste or odour do play part. Plant characteristics determining ingestibility such as easiness to chew and swallow were reported to

influence preference (Boumont *et al.*, 2003) especially when contrasting forages are combined. In the present study, however, the higher bite mass noted where *P. purpureum* was combined with other grass forages reflected that the highly preferred species could also be determined by considering specific forage species included in the mixture. This would also be an important strategy for improving DM intake and increased production with diets based on these local forages.

Digestibility had been indicated to influence forage preference such that the highly digestible forages would be more favoured (Lu, 1988). However, in such short-term trials like this one it is unlikely that digestibility of materials would have influenced preferences. Nevertheless, tastes, feel and odour of the feeds could also have impacted on the observed situation because animals develop the ability to recognise plant species by these features. This was also described by De Rosa *et al.* (1997) Boumont *et al.* (2003) who noted that free grazing cattle and goats may recognise tastes, feel and odour of different plants such that they adapt their grazing environment through the developed skills of identifying various plants.

4.5.3.2 Experiments on intake and animal performance based on green grass diets

4.5.3.2.1 Determination of intake and growth performance of crossbred calves fed local grass forages

Least square means for DM and ME intake are shown in Table 56. Mean intake for individual animals and economic estimates during feeding are shown in Appendix 9.

Analysis of variance results are indicated in Appendix 13. Supplementation positively improved the total DMI of all grass diets regardless of whether they were mixed or not (Table 56) but DM intake of forages of $80 \text{ g/kgW}^{0.75}$ for T1 was significantly higher ($P < 0.01$) than that of T2. Similarly, supplementation significantly ($P > 0.01$) effected DMI (%LW) of the mixed green grasses (T2 versus T4). In the absence of supplementation, forage DMI (%LW) of the mixed grasses (T4) was about 20 units higher than that of single grass forages (T3) but the difference was not significant ($P > 0.01$).

Total ME intake for animals on supplemented forages at $0.430 \text{ MJ ME/kgW}^{0.75}$ was significantly ($P < 0.01$) higher in T1 than the rest of the treatments (Table 56). This was four times higher in supplemented than in un-supplemented forages. In the absence of supplementation, mixing of forages led to higher ME intake than feeding of single grasses but the difference was not significant ($P > 0.01$).

Least square means for growth and feed conversion ratio for growing crossbred calves based on green grass forages is shown in Table 57, whereas individual weights and gains of the animals and analysis of variance for the parameters are shown in Appendix 10 and 13 respectively. Concentrate supplementation significantly ($P < 0.05$) influenced changes in weight gains and heart girths regardless of whether the forages were fed singly or mixed. This type of feeding regime increased the average daily gains for approximately two times between the supplemented and the non-supplemented green grasses (i.e. 542.79g/day and 259.11g/day or 478.45 g/day and 225.57g/day) for T1 and T3 or T2 and T4

respectively. The gains in weights and heart girths were the lowest in single and un-supplemented *P. maximum* (T3). The efficiency of feed utilization (FCR) was significantly ($P < 0.05$) greater for bull calves on supplemented forages (T1 and T2) than for the un-supplemented ones (T3 and T4). Practically, approximately 7 kg and 12kg of feed would be required to attain one kg of gain through supplementation and no supplementation respectively (Table 57).

Daily harvesting of grass and other forage resources fed to cattle was the usual practice in the SPD system of the study area. This is common in other parts of Tanzania and many other tropical countries where smallholder dairying is practiced. This cut and carry system was likely to provide forages with varying nutrient contents (Table 50 (a) and Table 50 (c)) because of the variations in sources and types of the forages used. Nevertheless, these results were based on a practical situation in smallholdings in feeding animals that have higher nutrient demands such as growing calves. Another crucial aspect observed was the low nutritive value of the grass species. Factors that limit productivity from grass and other tropical forages include their quality such as lower digestibility and low CP contents in grasses that can be alleviated through proper feeding strategies. Other authors (Leng, 1997; Shem *et al.*, 1999 and Khy *et al.*, 2000) have reported on various types of forages, strategies used in different production systems and the impact these feeds may have on performance of growing cattle or milking cows both in zero and free grazing situations.

Table 56. Least square means of DM and ME intake by calves during the growth study

	Treatment				SEM	SL
	T1	T2	T3	T4		
Number of animals	5	5	5	5		
Forage DMI						
g/d	2773.54 ^{ab}	2614.33 ^b	3100.75 ^a	2779.41 ^{ab}	150.24	*
g/kgW ^{0.75}	80.50 ^b	73.77 ^c	90.59 ^a	92.52 ^a	2.50	**
%LW	2.48 ^b	2.25 ^b	2.80 ^a	2.98 ^a	0.08	**
Supplement						
g/d	912.60 ^a	912.60 ^a	-	-	-	NS
Total DMI						
g/d	3686.14 ^a	3526.93 ^{ab}	3100.75 ^{bc}	2779.41 ^c	150.24	**
g/kgW ^{0.75}	107.33 ^a	99.98 ^{ab}	90.59 ^{bc}	92.52 ^c	2.49	**
%LW	3.31 ^a	3.06 ^{ab}	2.80 ^b	2.98 ^b	0.09	**
ME intake						
MJ ME /kgW ^{0.75}						
Forage	0.102 ^b	0.098 ^b	0.114 ^a	0.124 ^a	0.001	**
Total	0.430 ^a	0.420 ^a	0.114 ^b	0.124 ^b	0.002	**

^{a,b,c}Means within the same row with different superscripts differ significantly (P < 0.05)

^{a,b,c}Means within the same row with different superscripts differ significantly (P < 0.01)

SL = Significance level * *Significance level P < 0.01 *Significance level P < 0.05

NS= Not significant

SEM = standard error of mean

T1 = *Panicum maximum* (plus concentrate supplement)

T2 = *Panicum maximum* + *Panicum trichocladum* (in 5:1 ratio) (plus concentrate supplement)

T3 = *Panicum maximum* (without concentrate supplement)

T4 = *Panicum maximum* + *Panicum trichocladum* (in 5:1 ratio) (without concentrate supplement)

Table 57. Least square means (\pm SEM) of growth performance and feed conversion ratio of crossbred bull calves under different forage diets

	Treatment				Significance
	T1	T2	T3	T4	
Number of calves	5	5	5	5	
Age (Months)					
Start	8.5	8.5	8.5	8.5	
End	12.5	12.5	12.5	12.5	
Live weight (kg)					
Initial	88.97 \pm 4.73 ^a	94.17 \pm 4.73 ^a	96.63 \pm 4.73 ^a	83.00 \pm 4.73 ^a	*
Final	139.54 \pm 1.96 ^a	133.75 \pm 1.99 ^a	114.01 \pm 2.05 ^b	110.99 \pm 2.11 ^b	***
Gain	48.85 \pm 1.96 ^a	43.06 \pm 1.98 ^a	23.32 \pm 2.05 ^b	20.30 \pm 2.11 ^b	***
Growth rate (g/day)	542.79 \pm 21.82 ^a	478.45 \pm 22.10 ^a	259.11 \pm 22.78 ^b	225.57 \pm 23.46 ^b	***
Heart girth (cm)					
Initial	107.00 \pm 1.91 ^{ab}	108.13 \pm 1.91 ^a	107.87 \pm 1.91 ^a	101.67 \pm 1.91 ^b	*
Final	118.40 \pm 1.66 ^a	119.66 \pm 1.70 ^a	112.91 \pm 1.69 ^b	109.39 \pm 1.91 ^b	*
Gain	12.24 \pm 1.66 ^a	13.49 \pm 1.70 ^a	6.74 \pm 1.69 ^b	3.21 \pm 1.91 ^b	*
FCR	6.89 \pm 0.44 ^c	7.30 \pm 0.45 ^{bc}	11.56 \pm 0.47 ^a	13.28 \pm 0.48 ^a	*

FCR = feed conversion ratio SEM = standard error of mean

^{a,b,c}Means within the same row with different superscripts differ significantly at respective significant level:

* (P < 0.05); *** (P < 0.001);

T1 = *Panicum maximum* (plus concentrate supplement)

T2 = *Panicum maximum* + *Panicum trichoclaetum* (in 5:1 ratio) (plus concentrate supplement)

T3 = *Panicum maximum* (without concentrate supplement)

T4 = *Panicum maximum* + *Panicum trichoclaetum* (in 5:1 ratio) (without concentrate supplement)

The increased growth rates for bull calves that were on supplemented diets were associated with respective increase in DMI and the increase in CP content that has significant influence on rumen microbe production and efficiency. The concentrate mixture used in the study had about 18% CP and was expected to provide 12.23 MJ ME/kg DM for grasses with CP 6 – 7% and 10–11 MJ ME /kg DM. The daily gain of 0.5kg/day from the diet was approximately attained under T1 but slightly lowered in T2. Under general field conditions, however, the cut and carry system was likely to include grass forages with more or less variation than that assumed in initial estimates because of differences in sources or stages of maturity. For example, grass forages from unfertilized pastures were reported (Moss, 2003) to contain as low as 7 MJ ME/kg DM and 6 – 10% CP. On the other hand, the increased DMI as %LW that were observed in the present study were the result of intake of more roughage to which the calves were subjected. Unfortunately, however, this increase in roughage was more expensive especially on the un-supplemented groups. Findings similar to these have been reported before (Stock *et al.*, 1990; Khy *et al.*, 2000) where increase in fibre content in the diet led to corresponding increase in DM intake on %LW basis.

The post weaning growth rates recorded in supplemented versus un-supplemented diets conformed to the importance of good nutrition to livestock in smallholder and other livestock systems. However, gain in weight and the feeding practice to achieve the intended growths (gains) depends on various factors including breed, sex, physiological age, feeding strategy and health. In higher input systems, growth rates

of heifers of 0.7 -1.0kg/day have been reported (Moss, 2003) but diets that provide as high as CP 16% and 11 MJ ME/kg DM respectively would be needed. Within similar production systems, Rouquette *et al.* (2004) observed post-weaning gains of up to 454g/day and 590g/day in crossbred steers grazing un-supplemented and supplemented high quality grass based diets respectively. The growth rates of 225g/day – 258g/day recorded in the present study for the un-supplemented forages diets were within ranges that have been reported elsewhere for tropical forages (Raja *et al.*, 1981; Moss and Murray, 1992). These lower growth rates recorded especially in un-supplemented forages were also associated with the lower ME intakes, digestibility and the low CP levels of the grasses.

Mixing of green grass forages had no significant ($P > 0.01$) influence on monthly gross return and gross margins in feeding the growing bulls in the SPD farming system (Table 58). However, supplementation significantly ($P < 0.01$) affected both gross returns and gross margin. This was further illustrated by the gross return of Tsh. 19,929; 18,921; 11,564 and 8,848 that would be realized from the supplemented T1 and T2 and un-supplemented T3 and T4 respectively. In the supplemented or un-supplemented cases, however, monthly weight gains of 31.63kg and 30.03kg or 18.35kg and 14.04kg were achieved. Despite the great potential for monthly gains in margin through supplementations, it was felt more reasonable (at least for a short term) to feed un-supplemented *P. maximum* alone (T3) than combining it with *P. trichocladum* (T4).

Table 58. Costs and returns (\pm SEM) of feeding growing bull calves with green grass forages and concentrates

	Treatment			
	T1	T2	T3	T4
Number of calves	5	5	5	5
Mean price/kg LW (Tsh)	630	630	630	630
Final weight/head (kg)	139.54 \pm 1.96 ^a	133.75 \pm 1.99 ^a	114.01 \pm 2.05 ^b	110.99 \pm 2.11 ^b
Weight gain (Cumulative) (kg)	31.63 \pm 2.87 ^a	30.03 \pm 2.87 ^a	18.35 \pm 2.87 ^b	14.04 \pm 2.87 ^b
Cash costs monthly				
Feeds (Tsh)				
Concentrates (Tsh)	3011	3011	-	-
Labour <i>P.trichocladum</i> (Tsh)	-	750	-	750
Total variable cost (Tsh)	13210 ^b	13961 ^a	10200 ^d	10950 ^c
Gross return (Tsh)	19929 \pm 1808.31 ^a	18921 \pm 1808.31 ^a	11564 \pm 1808.31 ^b	8848 \pm 1808.31 ^b
Gross margin (Tsh/calf)	6718.2 \pm 1808.31 ^a	4960.2 \pm 1808.31 ^a	1364 \pm 1808.31 ^b	-2102 \pm 1808.31 ^b

^{a,b,c}Means within the same row with different superscripts differ significantly ($P < 0.01$)

SEM = standard error of mean

T1 = *Panicum maximum* (plus concentrate supplement)

T2 = *Panicum maximum* + *Panicum trichocladum* (in 5:1 ratio) (plus concentrate supplement)

T3 = *Panicum maximum* (without concentrate supplement)

T4 = *Panicum maximum* + *Panicum trichocladum* (in 5:1 ratio) (without concentrate supplement)

Although fast growth rates could be realized through supplementation of the green grasses, the costs and benefits associated with the practice depended on other factors on the ground. Normally, farmers in the SPD opted to give energy and protein supplements to milking cows and pre-weaned female calves instead of growing bull calves. As a result, many farmers were unlikely to keep bull calves until they were 110 – 140kgLW. On the other hand, the grass forages were almost free but the lower market price (Tsh. 630) paid per kgLW of the cattle sold in the area was likely to deter smallholder farmers from supplementing bull calves. Therefore, farmers' choices of which classes of cattle to supplement was one way of allocating resources to which a farmer has comparative advantage. The practice was also a measure of cutting down production costs. This was also compounded by the fact that the relatively higher cost for commercial concentrates increased total variable costs and may have hampered regular purchases. Field observation had also shown that the commercial energy and protein concentrates were often in short supply thus not practically suited as regular supplements. Therefore, more emphasis on proper management and utilization of alternative sources of protein supplements such as legumes and forbs may offer the desirable effects of fast gains and reduce costs as has been reported elsewhere (Shem *et al.*, 1999; Simbaya, 2002).

Furthermore, FCR indicated further that for 1kg of weight gain to be attained approximately 7kg of feed of the supplemented diet had to be offered. This was a far better performance (conversion) than the 11 – 13kg of feed that would be needed to attain 1kg in un-supplemented calves. This also supports the views of supplementing the basal grass diets for improved performance (Simbaya, 2002).

Therefore, the results in the present study may be compared with that of some studies in this scenario. For example, Khy *et al.* (2000) reported that 5 - 6 kg of feed were needed for the gain of 1kg for finishing steers under leucaena and lucerne based supplement compared to 7kg of feed required for 1kg gain with a conventional soybean based concentrate. On the other hand, Ahmed and Pollot (1977) reported feed conversion of 7.8, 6.6 and 5.8 in growing zebu calves under varying protein levels at average intakes of 2.0, 2.5 and 2.7kg hay DM/day and 2.3, 2.5 and 2.3kg concentrate DM/day respectively.

The overall trend of the present results for intake and growth of bull calves based on supplemented grasses may not be a surprise and could be expected at feeding regimes of adequate or higher levels of nutrient supply and intake. This is crucial for good performance of growing animals such as those used in the present study. Nevertheless, the slower weight gains for animals without concentrate supplementation, the 'almost free' grasses fed to cattle and the relatively higher costs incurred through supplementation bring about mixed feelings of promoting concentrate supplementation to bull calves. As a result, there may arise arguments that the economic analysis may not be relevant to a farmer in the SPD. However, these results could be related to advocacies on profitable enterprising and other social gains applicable in mixed production systems. This is because financial returns are not the only benefits that smallholder farmers consider in livestock keeping. Other non-financial gains such as manure and social *status quo* are also accounted for in keeping livestock (Moll, 2004). In some situations, for example, individual farmers

would like to keep a bull for breeding purposes. However, other farmers could also use the bull kept by one farmer although with a little fee or not. In either case, the bull accounts for raising the social status to the keeper. In most cases, breeding bulls kept in this manner are important particularly because coordinated breeding programs by the extension service or other governmental and non-governmental organizations were lacking in the SPD, as is the case in many villages in the country. These financial and non-financial benefits observed in the SPD were also reported in other smallholder production systems (Maruo, 2002; Bebe *et al.*, 2003a).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Overview

Information from literature reviews and empirical studies in this thesis brought to light significant features in the application of LK in agricultural production in general and in forage evaluation in particular. However, the strengths and weaknesses of the LKS were also noted. This final chapter draws conclusions and recommendations emanating from the study.

5.2 Conclusions

Farmers' experimentations in crop production and in livestock feeding were done in the SPD system of Turiani division. These experiments were a blend of own intuitions, local traditions, climatic and socio-economic conditions as well as externally imposed interventions and were employing both local methods and 'formal scientific' methods of experimentation.

Choices of forages to be used (or not to be used) under local conditions of Turiani division were based on multiple quality criteria associated with multiple objectives of livestock keeping. These included the role of animals in production, availability of

Concentrate supplementation of bull calves under the cut and carry system of the SPD may not be of direct financial gains to the smallholder farmer. However, there are other non-financial benefits tied to bull keeping and cattle husbandry in general. Therefore, proper utilization of alternative energy and protein rich feeds and improved marketing infrastructure are equally essential for optimizing the socio-economic gains of the cattle enterprises.

5.3 Recommendations

Local knowledge in livestock feeds and feeding must be tapped and where necessary be improved for the benefit of all the involved parties i.e. farmers, researchers and extension agents, with a general view of sustainable productivity of tropical livestock systems.

External intervention for improved crop and livestock productivity could be enriched with local knowledge and the farmers' experiences associated with biological, economic and social outlook.

Participatory approaches in acquisition of LK by 'formal' scientists must be promoted so that smallholder farmers might understand better some operations and processes in agricultural production than they currently do.

The road map to sustainable livestock production in smallholder systems must insist on immediate and deliberate efforts to integrate local and contemporary scientific knowledge in such a way that a brick laid by the LK is cemented by contemporary scientific understanding and *vice versa*.

As much as the rate of eating is used to describe forage preferences, farmers should consider the type and level of inclusion of different forage species in the offered mixtures in order to optimize DM intake.

More studies are still needed in local and complementary knowledge systems for sustainable utilization of feeds and other resources abundant in smallholder settings.

Future studies in LK must also employ contemporary data acquisition and analytical techniques including the use of geographical information systems (GIS) and computer modeling approaches.

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Table 25. Frequency (Percentage*) of ranking various grass species based on animal preference criterion by seasons

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
1	very poor	0	0	1 (70.0)	0	2 (14.3)	1 (20.0)	0	17 (13.6)
	poor	0	0	3 (15.0)	1 (5.3)	0	0	0	4 (3.2)
	good	4 (14.8)	19 (63.3)	1 (5.0)	10 (52.6)	10 (71.4)	1 (20.0)	3 (30.0)	48 (38.4)
	very good	23 (85.2)	11 (36.7)	2 (10.0)	8 (42.1)	2 (14.3)	3 (60.0)	7 (70.0)	56 (44.8)
	Total**	27 (21.6)	30 (24.0)	20 (16.0)	19 (15.2)	14 (11.2)	5 (4.0)	10 (8.0)	125 (100)
2	very poor	0	0	14 (66.7)	0	2 (8.7)	0	0	16 (11.3)
	poor	0	0	6 (28.6)	2 (8.79)	4 (17.4)	3 (42.9)	1 (10.0)	16 (11.3)
	good	7 (25.0)	7 (23.3)	1 (4.8)	20 (87.0)	12 (52.2)	2 (28.6)	4 (40.0)	53 (37.3)
	very good	21 (75)	23 (76.7)	0	1 (4.4)	5 (21.7)	2 (28.6)	5 (50.0)	57 (50.0)
	Total**	28 (19.7)	30 (21.1)	21 (14.8)	23 (16.2)	23 (16.2)	7 (4.93)	10 (7.04)	142 (100)

Table 25. continued

Season	Rank	Grass species							Total
		I	II	III	IV	V	VI	VII	
3	very poor	0	0	0	0	0	1 (7.1)	0	1 (0.7)
	poor	0	0	3 (12.0)	1 (4.0)	1 (4.4)	1 (7.1)	0	6 (3.9)
	good	2 (7.4)	3 (10.0)	17 (68.0)	18 (72.0)	17 (73.9)	9 (64.3)	5 (55.6)	71 (46.4)
	very good	25 (92.6)	27 (90)	5 (20.0)	6 (24.0)	5 (21.7)	3 (21.4)	4 (44.4)	75 (49.0)
	Total**	27 (17.7)	30 (19.6)	25 (16.3)	25 (16.3)	23 (15.0)	14 (9.2)	9 (5.9)	153 (100)
4	very poor	0	0	0	0	0	1 (5.9)	0	1 (0.6)
	poor	0	0	1 (3.5)	1 (3.5)	0	0	0	2 (1.2)
	good	4 (13.8)	2 (6.7)	24 (82.8)	22 (75.9)	20 (80.0)	13 (76.5)	3 (33.3)	88 (52.4)
	very good	25 (86.2)	28 (93.3)	4 (13.8)	6 (20.7)	5 (20.0)	3 (17.7)	6 (66.7)	77 (45.8)
	Total**	29 (17.3)	30 (17.9)	29 (17.3)	29 (17.3)	25 (14.9)	17 (10.1)	9 (5.4)	168 (100)

*Percent within column indicate within species responses

**Total responses and respective percent for respective season

Seasons: 1. Cool / Dry (July / August) 2. Dry (September / October)
3. Short rain (December / January) 4. Long rain (April / May)

Grass species: I = *Pennisetum purpureum* II = *Panicum maximum*
III = *Roetboellia cochinchinensis* IV = *Panicum trichocladum*
V = *Cynodon* spp VI = *Digitaria* spp VII = *Tripsacium laxum*

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APPENDICES

Appendix 1(a). Checklist and other tools used during the PRA in the identification and description of the nutritive values of forages

Checklist

- Major /most important forages for various classes of livestock
- Other forages and feeds used (if any)
- Sources of feeds
- Criteria for quality description
- Quality in relation to seasons
- Deliberate effort to sustain / maintain quality
- What is done to maintain species of value
- NOTE : Views by gender, different generations (age groups etc)

Other tools

- Direct observation
- Pairwise ranking
- Matrix ranking
- Absolute scoring
- Pic charts
- Seasonal calendars

Appendix 1(b). Key informants interviewed in Phase 1

Village	Interviewee	Position
Lungo	Mbonea Joseph Msuya (Mr)	Farmer, Village Executive Secretary
	Enary Said (Mr)	Farmer, Village Chairman
	John Mgonja (Mr)	Farmer
	G. Mwenda (Mr)	SURUDE Farm Manager*
Kidudwe	Iddi Halfan Msakuzi (Mr)	Farmer, Village Executive Secretary
Kunkhe	Isack Charles Andrew (Mr)	Farmer, Village Executive Secretary
Kichangani	Farida Mungi (Ms)	Farmer, Village Chairperson
	Ahmad Salim (Mr)	Farmer
Manyinga	Selemani Simbano	Farmer, Secretary to cattle keepers' group

Appendix 2: The English version of questionnaire 1: Characteristics of the crop – livestock production system of Turiani division with respect to feeding of local and improved cattle

1.0. General

- 1.1. Questionnaire No
- 1.2. Name of enumerator.
- 1.3. Date
- 1.4. Village
- 1.5. Average altitude
- 1.6. GPS Co-ordinates
Eastings (Latitude)Southings (Longitude)
- 1.7. Ward
- 1.8. District

2.0. Household

- 2.1. Name of interviewee.....
- 2.2. Gender: Male / Female
- 2.3. Age (Years
- 2.4. Education
- 2.5. Number of people in the household
- 2.6. Children below 15yrs
- 2.7. Children over 15 years
- 2.8. Members living away from home / working in town.....
- 2.9. What do you say about your residence in this place?
a) born in this village b) moved into the village (Tick one- ✓)
- 2.10. 1. If moved into the village, how long have you been living in this village? Number of years
- 2.10.2. Where were you living before you moved into this village
- 2.10.3. Is your formal village within Turiani division a) YES b) NO

3.0. Field crop production

- 3.1. How many fields do you have?
- 3.2. How much land do you own (acres)?
- 3.3. Would you like to cultivate more land
- 3.4. What is the distance from home to your fields?
- 3.5. How do you operate during planting season / weeding (Tick- ✓)
a) Whole family shift to shamba / fields
b) Adults only shift to shamba
c) Operate from home daily
d) Other methods (Specify)
- 3.6. How do you operate during harvesting (Tick- ✓)
a) Whole family shift to shamba / fields
b) Adults only shift to shamba
c) Operate from home daily
d) Other methods (Specify)

3.7. Do some of your plots lie fallow? (Tick- ✓)

- a) Yes b) No

3.8. Reason for lying fallow

3.9. Reason for No fallow

3.10. Are soils in your plots good or bad as seen in relation to the soils in the village?

.....

3.11. Has the soil changed over the years? YES / NO

.....

4.0. Crop management

4.1. How much land did you cultivate last season? (Acres)

4.2. How much land did you cultivate this season? This season (acres)

4.3. What crops do you often grow (every year/season)?

Sole crop	Combination
1.	1.
2.	2.
3.	3.
4.	4.

4.4. Use of different crops

Crop	Uses
1.	_____
2.	_____
3.	_____
4.	_____

4.5. For how many (seasons) years have you been growing this combination of crops?

.....

4.6. What input do you use in your production? (Tick- ✓)

- a) Draught b) tractor c) chemical fertilizer
 d) Manure e) improved seeds

4.7. Which do you purchase?

.....

4.8. Which do you hire?

.....

4.9. Has the amount of purchased input changed over years?

.....

4.10. Any desires to change the amount of used input in your production?

.....

4.11. What are the reasons for any change?

4.12.1. How do you utilize crop residues when you have harvested your crops? (Tick- ✓ all possible answers)

- a) Grazed in situ by my own animals b) Grazed in situ by other peoples' animals
 c) Collected and brought home for animal feeding

4.12.2. What are common problems that you face if you use crop residues for animal feeding?

4.12.2. How do you cope with them?

4.13. Do you conduct any small experiments / trials in your daily activities in order to get experience and knowledge as a way to improve crop management practices?

4.14. If small experiments / trials are conducted, are they continued or integrated in the whole production process?

4.15. Has any of the "tricks" in your practice been copied by any of the farmers you know?

4.16. What can you advise other Turiani farmers to do especially based on your experience in crop production?

5.0. Livestock

5.1. Number:

- 5.1.1. Improved Cows Calves Yearling Bulls
 5.1.2. Local Cows Calves Yearling Bulls
 5.1.3. Sheep
 5.1.4. Goats
 5.1.5. Pig
 5.1.6. Chicken

5.2. Who owns (Tick- ✓)

Livestock	Husband	Wife	Both	Others
Cattle				
Sheep				
Goat				
Chicken				
Pig				
Others (mention)				

5.3. Livestock fodder supply and practice

5.4. How do you feed your livestock?

- a) Zero grazing b) free range c) combination of both d) Tethering

5.5. If you ZERO GRAZE only, do you consider areas where forages are obtained sufficient for forage supply throughout the year? (Tick- ✓)

- a) Yes b) No

5.6. If you FREE GRAZE only, do you consider areas where forages are obtained sufficient for forage supply throughout the year? (Tick- ✓)

- a) Yes b) No

5.7.1. Explain any coping strategies with forage deficit

5.7.2. Do you offer supplementary feeds? Yes / No

5.7.3. Which ones (Mention)

5.7.4. For which type / class of livestock?

5.8. Please mention some grass forages and their availability according to season (Wet / Dry – Month)

J/F F/M M/A A/M M/J J/J J/A A/S S/O O/N N/D
D/J

Grass forage	Month	Season

5.9. What are the things that you consider (criteria) when you say that particular grass forage IS GOOD?

- 1..... 2.....
3..... 4.....
5..... 6.....
7..... 8.....
9..... 10.....

5.10. Are there particular things / effort that you do to make sure that GOOD grass forages are easily available for your animals?

.....
.....

5.11. What are the things that you consider (criteria) when you say that particular grass forage is NOT GOOD (BAD)?

- 1..... 2.....
3..... 4.....

- 5..... 6
- 7..... 8
- 9..... 10

5.12. What do you do when there are those BAD grass forages?

.....

5.13. Please mention some legume forages and their availability according to season (Wet / Dry – Month)

J/F F/M M/A A/M M/J J/J J/A A/S S/O O/N N/D
 D/J

Legume	Month	Season

5.14. What are the things that you consider (criteria) when you say that a particular legume IS GOOD?

- 1..... 2
- 3..... 4
- 5..... 6
- 7..... 8
- 9..... 10

5.15. Are there particular things / effort that you do to make sure that GOOD legumes are easily available for your animals?

.....

.....

5.16. What are the things that you consider (criteria) when you say that a particular legume is NOT GOOD (BAD)?

- 1..... 2
- 3..... 4
- 5..... 6
- 7..... 8
- 9..... 10

5.17. What do you do when there are those BAD legumes?

.....

5.18. Please mention some trees/ shrubs you know that goats or cows browse on (Use any language – Mention the language used to identify)

- 1 2 3.....
- 4..... 5..... 6.....
- 7..... 8..... 9.....

5.19. What are the things that you consider (criteria) when you say that a particular tree/shrub is NOT GOOD ('BAD')?

- | | |
|--------|--------|
| 1..... | 2..... |
| 3..... | 4..... |
| 5..... | 6..... |
| 7..... | 8..... |
| 9..... | |

5.15. In which season are the mentioned trees / shrubs favourable:

J/F F/M M/A A/M M/J J/J J/A A/S S/O O/N N/D
 D/J

Tree / shrub	Month	Season

5.16. Do you conduct any small experiments / trials in your daily activities as far as management of your animals is concerned?

a) YES b) NO (Tick- ✓)

If YES Specify

5.17. Please mention some crop residues and their availability according to season (Wet / Dry - Month)

J/F F/M M/A A/M M/J J/J J/A A/S S/O O/N N/D
 D/J

Legume	Month	Season

5.18. What do you say about the various crop residues that are available for your animals?

Crop residue	Explanation	
	Quantity	Quality

5.19. If small experimental trials are conducted, are they continued or integrated in the whole production process?

.....

5.20. Has any of the "tricks" in your practice been copied by any of the farmers you know?

.....

5.21. How do you dispose manure from your kraal?
.....

5.22. How do you dispose residual feed?

5.23. How is your herd / cow compared to cows/ herds of other farmers? (Tick- ✓)

- a) Excellent b) good c) similar d) can't say anything

5.24. Are there any changes between seasons?
.....

5.25. What causes the changes?
.....

5.26. Are you proud of your current breed of cattle?
.....

5.27. What are major diseases that affect your animals?

- 1..... 2..... 3.....
4 5

5.28. What are the coping strategies?
.....
.....
.....

5.29. Have you been to any training / workshop / seminar on livestock management? a) YES
b) No

5.30. If YES, a) When? b) Where?

c) How has this influenced your activities in feeding?
.....

d) How has this influenced your activities in disease control?
.....

6.0. Livestock and manure

6.1. How do you utilize manure produced in your boma?
.....

6.2. (If used for fertilizing crop fields) How many fields receive manure?

6.3. Which crops?
.....

6.4. How is the work done?
.....

6.7. Is there enough manure to meet requirements?
.....

6.8. What do you advise other Turiani farmers to do especially based on your experience in livestock production?

.....

7.0. Labour

7.1. Labour division by gender in different enterprises

Gender	Enterprise	Job
Male	Livestock	
Female	Livestock	
Gender	Enterprise	Job
Male	Crop	
	other	
Female	Crop	
	Other	

7.2. Any changes in job distribution over years?

7.3. What caused the changes?

7.4. Need more labour for particular job in growing crops?

7.5. Do you hire labour? A) YES b) No

7.5.1. What job?

7.5.2. What price?

7.5.3. Any particular skills for a household member

8.0. Farmer collaboration

8.1. Is this a common practice?

8.2. Which jobs?

8.7.3. How did it began?

8.4. Benefits

8.5. Problems

8.6. Formalization of collaboration?

9.0. Relationship with the village

9.1. Is there any restriction by the village authorities on how household could run?

9.2. Are there any guidance or by laws on how production in the household should be conducted?
 Crop
 Livestock

9.3. What are the different institutions which support if something happens to the household?

10.0. Economic structure of a household?

10.1. Split areas of control for husband and wife:

10.2. Who gets income from different products?

Gender		
Male	Female	Both

10.3. From which products do the husband and wife respectively get the income?

10.3. Who takes decision in the different areas of concern?

(H = Husband W = Wife B = both)

- 9.3.1. Crop production.....
- 9.3.2. Cattle management
- 9.3.3. School fees
- 9.3.4. Private matters?

10.4. Who takes the decision of buying inputs for the household and the production respectively? (H = husband W = Wife B = both)

11.0 Market

11.1 Which products are sold?

11.1.1 Crop

-
11.1.2. Livestock
-
11.2. To who do you sell? (Access to market)
- 11.3. Any particular problems concerning sales?
 - Distance
 - Transportation
 - Price of products / produce

- 11.4. Has the market system changed over the years?

- 11.5. Has the system been better or worse?

- 11.6. Why do you say so?

- 12.0. Costs**

- 12.1. Cost of production last season
 - 12.1.1. Seeds.....
 - 12.1.2. Fertilizer
 - 12.1.3. Veterinary
 - 12.1.4. Hired labour
 - 12.1.5. Hired draught animals
 - 12.1. 6. Others
 - 12.1. 6.1. School fees
 - 12.1. 6.2. Transport
 - 12.1. 6.3. Health
 - 12.1. 6.4. Wedding
 - 12.1. 6.5. Others

**THANK YOU FOR YOUR CO-OPERATION AND FOR ENLIGHTENING ME ON
YOUR AGRICULTURAL ACTIVITIES**

Appendix 3. The English version of questionnaire 2: Farmers' assessment of quality of different forage species in the SPD farming system of Turiani (Longitudinal survey)

Name of respondent Village Date
 Male/ Female Age Owner/ Assistant

Forage (Grasses)	Criteria for Quality							
	Preference (how craved for on offer)	Increase milk yield	Stomach fill	Availability	No diarrhoea	Milk quality	Heathy animal	Convenience-cut/carry
<i>P. purpureum</i>								
<i>P. maximum</i>								
<i>R. cochinchinen.</i>								
<i>P. trichocladium</i>								
<i>Cynodon</i> spp								
<i>Cynodon</i> spp								
<i>T. laxum</i>								
Kiwawe								
<i>Brachiaria</i> spp								
<i>Sorghum</i> spp								

*Score: 4 = Very good 3 = Good 2 = Poor 1 = Very poor

Forage (legumes/forbs)	Criteria for Quality									
	Preference (how craved for on offer)	Increase milk yield	Stomach fill	Availability	No diarrhoea	Milk quality	Heathy animal	Convenience-cut/carry		
<i>M. atropurpureum</i>										
<i>V. pubescens</i>										
<i>V. unguiculata</i>										
<i>I. aquatica</i>										
<i>C. africana</i>										
<i>M. pruriens</i>										
<i>M. sativa</i>										
Forage (trees/shrubs)										
<i>G. sepium</i>										
<i>L. leucocephala</i>										
<i>Morus</i> spp (<i>M. alba</i>)										
<i>S. stamea</i>										
<i>P. dulce</i>										
<i>F. virosa</i>										
<i>O. abyssinica</i>										
<i>S. sesban</i>										
<i>T. indica</i>										
<i>M. oleifera</i>										
<i>Grewia</i> spp										
<i>M. obtusifolia</i>										

*Score: 4 = Very good 3 = Good 2 = Poor 1 = Very poor

Appendix 4. Chemical composition of forages used in the growth experiment

Parameter	Forage grasses		
	<i>P. maximum</i>	<i>P. trichocladum</i>	<i>P. maximum</i> + <i>P. trichocladum</i>
DM ¹ (g/kg)	346.5	347.1	344.6
DM (g/kg)	917.2	915.7	922.4
Composition (g/kgDM)			
Ash	85.0	96.4	
CP	78.8	77.5	65.9
ADF	459.4	446.5	471.7
NDF	714.5	703.4	723.2
IVDMD	406.2	405.0	414.9
IVOMD	433.6	449.8	424.2
Ca	4.1	3.3	3.4
P	4.4	3.7	3.6
Energy ² (ME MJ/kg)	5.25	5.23	5.38

¹DM as fed

²Energy ME = Metabolizable energy [ME calculations were performed based on formula of MAFF (1975) as cited by Bwire *et al.* (2003 page 96) whereby ME (MJ/kgDM) = 0.15 DOMD% and DOMD% = 0.98DMD% - 4.8]

Appendix 5. Fitted values for DM degradability estimates for grass forages

Forage No.	AnimNo	a	b	c	a + b	k2	Effective degradability.
1	1	13.04	49.76	0.019	62.8	0.05	36.9
1	2	14.05	57.55	0.012	71.6	0.05	36.1
1	3	10.56	51.67	0.031	62.23	0.05	41.8
2	1	11.3	46.03	0.029	57.33	0.05	38.4
2	2	13.45	54.11	0.015	67.56	0.05	36.7
2	3	12.07	46.32	0.042	58.39	0.05	43.5
3	1	12.57	48.29	0.017	60.86	0.05	35
3	2	11.84	47.29	0.022	59.13	0.05	36.5
3	3	10.43	48.87	0.032	59.3	0.05	40.4

Appendix 6. Fitted values for DM degradability estimates for concentrate feeds

Concentrate No.	AnimNo	a	b	c	potential degr (a+b)	48hrdeg (like invivo)	Effective degradability
1	1	31.92	51.91	0.094	83.83	83.27	74.7
1	2	51.21	44.67	0.042	95.88	90	81.5
1	3	29.54	66.11	0.0699	95.65	93.34	80.9
2	1	24.51	38.06	0.192	62.57	62.56	59
2	2	26.66	35.78	0.302	62.44	62.45	60.2
2	3	22.27	42.68	0.17	64.95	64.94	60.5
3	1	32.88	58.8	0.018	91.68	67.31	61
3	2	28.53	48.51	0.079	77.04	75.94	67.2
3	3	27.58	56.85	0.039	84.43	75.79	65.2
4	1	36.58	40.56	0.0598	77.14	74.84	67
4	2	37.64	42.9	0.0774	80.54	79.49	71.7
4	3	35.05	42.13	0.081	77.18	76.33	68.9
5	1	27.3	50.97	0.071	78.27	76.55	67.1
5	2	29.42	49.98	0.066	79.4	77.33	67.8
5	3	25.95	53.96	0.083	79.91	78.94	69.5

Appendix 7. Average individual quantities of single forage species consumed and behaviour of animals during preference study

Anim No.	Treatment (Spp)	Intake gDM	Intake rate gDM/Min	Intake g/kgLW ^{0.75}	Number of bites	Bites per minute	Bitemass gDM/bite
17	1	142.24	9.48	0.34	70.75	4.72	2.06
18	1	167.62	11.18	0.40	66.50	4.43	2.60
19	1	137.31	9.16	0.35	73.00	4.87	2.01
20	1	139.91	9.33	0.34	70.50	4.70	2.24
17	2	139.76	9.32	0.34	46.75	3.12	3.38
18	2	135.35	9.02	0.32	53.25	3.55	2.63
19	2	108.15	7.21	0.28	71.75	4.78	1.53
20	2	178.60	11.91	0.43	70.75	4.72	2.74
17	3	245.41	16.36	0.59	82.25	5.49	3.29
18	3	212.51	14.17	0.51	70.25	4.68	3.24
19	3	258.02	17.20	0.66	86.50	5.77	3.03
20	3	227.10	15.14	0.54	79.75	5.32	2.90
17	4	157.36	10.49	0.38	81.50	5.43	1.96
18	4	159.16	10.61	0.38	71.75	4.78	2.23
19	4	217.11	14.48	0.56	87.50	5.83	2.50
20	4	152.56	10.17	0.37	82.50	5.50	1.87

Appendix 8. Average individual quantities of mixed forage species consumed and behaviour of animals during preference study

Anim. No.	Treatment	Intake gDM	Intake rate gDM/Min	Intake g/kgLW ^{0.75}	Total bites	Bites per minute	Bitemass gDM/bite
17	1	165.36	11.03	5.99	58.00	3.88	2.85
18	1	184.13	12.28	6.58	56.75	3.79	3.25
19	1	151.78	10.12	5.78	59.50	3.97	2.62
20	1	139.53	9.30	5.01	60.75	4.05	2.31
17	2	169.58	11.31	6.14	70.50	4.70	2.41
18	2	177.95	11.86	6.36	68.50	4.57	2.60
19	2	179.26	11.95	6.83	87.75	5.85	2.08
20	2	163.04	10.87	5.85	83.75	5.58	1.95
17	3	218.58	14.57	7.91	72.50	4.83	3.02
18	3	217.12	14.48	7.76	71.25	4.75	3.05
19	3	251.74	16.78	9.59	86.50	5.77	2.96
20	3	210.71	14.05	7.56	90.00	6.00	2.35
17	4	240.18	16.02	8.70	66.00	4.40	3.67
18	4	216.61	14.44	7.74	66.50	4.43	3.28
19	4	253.66	16.91	9.66	72.25	4.82	3.53
20	4	219.62	14.64	7.88	76.50	5.10	2.87

Appendix 9. Average individual quantities of feeds offered and consumed and economic estimates for calves based on green grass forages

Anim.	Treat	Foraoffer	Forarefu	Grasseat	Concent	Totalint	Forambw	Totintmbw	Forint%	Totint%	TotalME	Totvarcos	Grosretu	Netretu
9703	1	3408.16	1060.31	2347.85	912.60	3260.45	75.35	104.70	2.40	3.33	0.45	96.34	62253.33	62156.99
9714	1	3598.16	805.77	2792.39	912.60	3704.99	79.01	105.02	2.41	3.21	0.42	81.65	73347.75	73266.10
9723	1	3713.03	691.02	3022.01	912.60	3934.61	86.81	113.45	2.67	3.49	0.44	77.22	71391.83	71314.61
9745	1	3645.94	856.97	2788.97	912.60	3701.57	80.87	107.48	2.49	3.31	0.43	81.56	71045.33	70963.78
9749	1	3655.07	738.59	2916.49	912.60	3829.09	80.46	105.99	2.44	3.22	0.41	79.02	75776.17	75697.15
9708	2	3558.40	950.75	2607.64	912.60	3520.24	73.54	99.42	2.24	3.03	0.41	90.82	73739.75	73648.93
9710	2	3920.10	737.85	3182.25	912.60	4094.85	80.75	104.13	2.38	3.07	0.39	76.09	84403.67	84327.58
9711	2	3149.08	982.13	2166.95	912.60	3079.55	71.48	101.92	2.30	3.28	0.48	109.42	59761.33	59651.92
9722	2	3521.72	987.89	2533.83	912.60	3446.43	66.25	90.28	1.97	2.69	0.38	93.04	81144.00	81050.96
9743	2	3491.34	910.37	2580.96	912.60	3493.56	76.84	104.13	2.38	3.23	0.44	91.62	68560.33	68468.71
9706	3	3914.26	816.58	3097.67	0	3097.67	88.73	88.73	2.72	2.72	0.11	66.32	71687.0	71620.68
9713	3	3887.60	626.89	3260.70	0	3260.70	95.70	95.70	2.95	2.95	0.12	62.07	69471.50	69409.43
9736	3	3598.93	825.93	2773.00	0	2773.00	85.11	85.11	2.67	2.67	0.11	73.12	65703.75	64966.50
9739	3	3532.39	823.79	2708.60	0	2708.60	87.07	87.07	2.77	2.77	0.11	74.59	61689.83	61615.25
9740	3	4538.40	874.64	3663.76	0	3663.76	96.35	96.35	2.87	2.87	0.12	56.06	80273.67	80217.60
9704	4	3425.05	953.27	2471.78	0	2471.78	80.11	80.11	2.56	2.56	0.11	86.68	61059.83	60973.15
9705	4	3857.80	784.04	3073.77	0	3073.77	98.63	98.63	3.14	3.14	0.13	68.83	61777.92	61709.09
9712	4	3721.26	647.88	3073.39	0	3073.39	93.94	93.94	2.94	2.94	0.12	69.02	65786.00	65716.98
9717	4	3038.53	623.68	2414.86	0	2414.86	94.38	94.38	3.20	3.20	0.13	87.83	47710.83	47623.00
9746	4	3515.03	651.77	2863.26	0	2863.26	95.54	95.54	3.08	3.08	0.13	73.43	58828.00	58754.57

Appendix 10. Individual initial, final weight, weight change and average gain per day of crossbred calves

Crate No.	Cattle No.	Treatment	Initial weight (kg)	Finalweight (kg)	Wchange (kg)	Avggain(g /d)	Avggain(k g/d)	Initial girth (cm)	Final girth (cm)
1	9745	1	89.50	134.17	44.67	496.30	0.50	104.00	119.07
2	9749	1	94.67	151.00	56.33	625.93	0.63	111.67	125.80
3	9703	1	80.00	120.67	40.67	451.85	0.45	105.67	109.36
4	9714	1	94.00	141.50	47.50	527.78	0.53	107.67	121.59
5	9723	1	86.67	140.33	53.67	596.30	0.60	106.00	121.07
6	9708	2	93.50	139.00	45.50	505.56	0.51	107.33	122.48
7	9743	2	90.00	127.67	37.67	418.52	0.42	104.67	115.46
8	9710	2	108.33	156.67	48.33	537.04	0.54	113.67	130.31
9	9722	2	107.33	148.33	41.00	455.56	0.46	113.00	127.62
10	9711	2	71.67	117.33	45.67	507.41	0.51	102.00	113.88
11	9736	3	88.50	114.00	25.50	283.33	0.28	105.33	111.40
12	9740	3	111.67	142.00	30.33	337.04	0.34	110.67	122.81
13	9713	3	97.33	119.33	22.00	244.44	0.24	109.00	115.77
14	9706	3	99.00	122.00	23.00	255.56	0.26	107.67	116.00
15	9739	3	86.67	107.33	20.67	229.63	0.23	106.67	108.50
16	9712	4	92.67	113.67	21.00	233.33	0.23	106.00	111.50
17	9704	4	87.67	104.33	16.67	185.19	0.19	105.67	105.00
18	9717	4	68.00	82.67	14.67	162.96	0.16	91.67	96.52
19	9746	4	81.17	102.17	21.00	233.33	0.23	102.67	106.16
20	9705	4	85.50	107.33	21.83	242.59	0.24	102.33	101.45

Appendix 11. ANOVA The GLM Procedure: Assessment of single forage preferences by cross-bred bull-calves

Appendix 11(a). ANOVA for total DM intake (dmi)

Source	DF	SS	MS	F Value	Pr > F
cr	3	1183.16475	394.38825	0.23	0.8721
dy(cr)	12	54741.40573	4561.78381	2.71	0.0117
order(cr)	12	18641.12248	1553.42687	0.92	0.5375
spp	3	90973.43863	30324.47954	17.98	<.0001
Error	33	55645.1860	1686.2178		
Corrected Total	63	221184.3176			

Appendix 11(b). ANOVA for intake rate gDM/ minute (indmi)

Source	DF	SS	MS	F Value	Pr > F
cr	3	5.2744172	1.7581391	0.23	0.8716
dy(cr)	12	243.3116688	20.2759724	2.70	0.0117
order(cr)	12	82.8571687	6.9047641	0.92	0.5376
spp	3	404.4884047	134.8294682	17.99	<.0001
Error	33	247.3663016	7.4959485		
Corrected Total	63	983.2979609			

Appendix 11(c). ANOVA for intake rate (g/LW^{0.75}) (inmbmin)

Source	DF	SS	MS	F Value	Pr > F
cr	3	0.02791250	0.00930417	0.89	0.4552
dy(cr)	12	0.32098750	0.02674896	2.57	0.0160
order(cr)	12	0.11178750	0.00931562	0.89	0.5375
spp	3	0.54833750	0.18277917	17.54	<.0001
Error	33	0.34397500	0.01042348		
Corrected Total	63	1.35300000			

Appendix 11(d). ANOVA for total number of bites (tbmi15)

Source	DF	SS	Mean Square	F Value	Pr > F
cr	3	1876.546875	625.515625	5.27	0.0044
dy(cr)	12	7688.812500	640.734375	5.40	<.0001
order(cr)	12	2386.312500	198.859375	1.67	0.1186
spp	3	4267.046875	1422.348958	11.98	<.0001
Error	33	3918.39063	118.73911		
Corrected Total	63	20137.10938			

Appendix 11(e). ANOVA for Bite rate (bpmin)

Source	DF	SS	MS	F Value	Pr > F
cr	3	8.34536719	2.78178906	5.28	0.0044
dy(cr)	12	34.15060625	2.84588385	5.40	<.0001
order(cr)	12	10.61125625	0.88427135	1.68	0.1180
spp	3	18.94594219	6.31531406	11.98	<.0001
Error	33	17.39922656	0.52724929		
Corrected Total	63	89.45239844			

Appendix 11(f). ANOVA for bite mass (bitmass)

Source	DF	SS	MS	F Value	Pr > F
cr	3	1.87431250	0.62477083	0.81	0.4971
dy(cr)	12	39.73216250	3.31101354	4.30	0.0004
order(cr)	12	10.53251250	0.87770937	1.14	0.3643
spp	3	9.41172500	3.13724167	4.07	0.0145
Error	33	25.43126250	0.77064432		
Corrected Total	63	86.98197500			

Appendix 12. ANOVA The GLM Procedure: Assessment of mixed forage preferences by cross-bred bull-calves**Appendix 12(a). ANOVA for total DM intake (dmint)**

Source	DF	SS	MS	F Value	Pr > F
cr	3	5464.46321	1821.48774	3.50	0.0263
dy(cr)	12	13523.82034	1126.98503	2.16	0.0396
Order(cr)	12	7664.01204	638.66767	1.23	0.3075
Sppmix	3	63612.01443	21204.00481	40.70	<.0001
Error	33	17194.0922	521.0331		
Corrected Total	63	107458.4022			

Appendix 12(b). ANOVA for intake rate gDM/ minute (inratdm)

Source	DF	SS	MS	F Value	Pr > F
cr	3	24.3042500	8.1014167	3.50	0.0261
dy(cr)	12	60.0686250	5.0057187	2.16	0.0396
Order(cr)	12	34.1190750	2.8432563	1.23	0.3058
Sppmix	3	282.9067875	94.3022625	40.75	<.0001
Error	33	76.3696375	2.3142314		
Corrected Total	63	477.7683750			

Appendix 12(c). ANOVA for intake rate (g/LW^{0.75}) (Intdmbwt)

Source	DF	SS	MS	F Value	Pr > F
cr	3	15.79629219	5.26543073	7.18	0.0008
dy(cr)	12	17.77144375	1.48095365	2.02	0.0547
Order(cr)	12	10.26609375	0.85550781	1.17	0.3454
Sppmix	3	85.74984219	28.58328073	38.98	<.0001
Error	33	24.1988391	0.7332982		
Corrected Total	63	153.7825109			

Appendix 12(d). Dependent Variable: Total number of bites (tbit15)

Source	DF	SS	MS	F Value	Pr > F
cr	3	1912.750000	637.583333	21.33	<.0001
dy(cr)	12	1524.500000	127.041667	4.25	0.0005
Order(cr)	12	863.500000	71.958333	2.41	0.0228
Sppmix	3	4394.625000	1464.875000	49.01	<.0001
Error	33	986.375000	29.890152		
Corrected Total	63	9681.750000			

Appendix 12(e). ANOVA for bite rate (bitepmin)

Source	DF	SS	MS	F Value	Pr > F
cr	3	8.48150469	2.82716823	21.40	<.0001
dy(cr)	12	6.77816875	0.56484740	4.27	0.0004
Order(cr)	12	3.85101875	0.32091823	2.43	0.0217
Sppmix	3	19.49751719	6.49917240	49.19	<.0001
Error	33	4.36048906	0.13213603		
Corrected Total	63	42.96869844			

Appendix 12(f). ANOVA for bite mass (bitmass)

Source	DF	SS	Mean Square	F Value	Pr > F
cr	3	4.49596719	1.49865573	13.15	<.0001
dy(cr)	12	3.80719375	0.31726615	2.78	0.0099
Order(cr)	12	2.79964375	0.23330365	2.05	0.0515
Sppmix	3	9.36796719	3.12265573	27.40	<.0001
Error	33	3.76151406	0.11398527		
Corrected Total	63	24.23228594			

Appendix 13: ANOVA The GLM Procedure: Intake and growth of crossbred bull calves**Appendix 13(a). ANOVA for Grass forage offered (Foraoffer)**

Source	DF	SSs	Mean Square	F Value	Pr > F
Treatment	3	474329.2798	158109.7599	1.83	0.1825
Error	16	1382912.295	86432.018		
Corrected Total	19	1857241.574			

Appendix 13(b). ANOVA for forage refused (Forarefu)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	86521.76212	28840.58737	1.94	0.1644
Error	16	238279.9578	14892.4974		
Corrected Total	19	324801.7199			

Appendix 13(c). ANOVA for forage grass eaten (Grasseat)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	624449.9907	208149.9969	1.84	0.1798
Error	16	1805709.206	112856.825		
Corrected Total	19	2430159.197			

Appendix 13(d). ANOVA for concentrate

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	4164193.800	1388064.600	Infty	<.0001
Error	16	0.000	0.000		
Corrected Total	19	4164193.800			

Appendix 13(e). ANOVA for total intake (Totalint)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	2542324.521	847441.507	7.51	0.0023
Error	16	1805709.206	112856.825		
Corrected Total	19	4348033.727			

Appendix 13(f). ANOVA for forage intake (metabolic weight – Forambw)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	1162.139920	387.379973	12.40	0.0002
Error	16	499.796560	31.237285		
Corrected Total	19	1661.936480			

Appendix 13(g). ANOVA for total intake (metabolic weight – Totintmb)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	875.9888000	291.9962667	9.43	0.0008
Error	16	495.244280	30.952767		
Corrected Total	19	1371.233080			

Appendix 13(h). ANOVA for forage intake (percent body weight – Forintperc)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	1.58074000	0.52691333	17.67	<.0001
Error	16	0.47724000	0.02982750		
Corrected Total	19	2.05798000			

Appendix 13(i). ANOVA for total intake (percent body weight – Totinperc)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	0.68520000	0.22840000	6.31	0.0050
Error	16	0.57952000	0.03622000		
Corrected Total	19	1.26472000			

Appendix 13(j). ANOVA for total metabolic energy intake (TotalME)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	0.46868000	0.15622667	310.90	<.0001
Error	16	0.00804000	0.00050250		
Corrected Total	19	0.47672000			

Appendix 13(k). ANOVA for total variable cost (Totvarcos)

Source	DF	SS	Mean Square	F Value	Pr > F
Treatment	3	1753.270135	584.423378	6.77	0.0037
Error	16	1381.923520	86.370220		
Corrected Total	19	3135.193655			

Appendix 13(l). ANOVA for gross return (Grosretu)

Source	DF	Squares	Mean Square	F Value	Pr > F
Treatment	3	606813073.7	202271024.6	3.69	0.0341
Error	16	876623361	54788960		
Corrected Total	19	1483436435			

Appendix 13(m). ANOVA for net return (Netretn)

Source	DF	Squares	Mean Square	F Value	Pr > F
Treatment	3	604099293.1	201366431.0	3.64	0.0355
Error	16	884228108	55264257		
Corrected Total	19	1488327401			

Appendix 13(n). ANOVA for average daily gain (Avdgain)

Source	DF	SS	MS	F Value	Pr > F
Treat	3	384593.4386	128197.8129	54.28	<.0001
Iniwt	1	6009.7089	6009.7089	2.54	0.1315
Error	15	35423.5777	2361.5718		
Corrected Total	19	426026.7252			

Appendix 13(o). ANOVA for weight change (Wchange)

Source	DF	SS	MS	F Value	Pr > F
Treat	3	3115.289560	1038.429853	54.32	<.0001
Iniwt	1	48.568574	48.568574	2.54	0.1318
Error	15	286.749546	19.116636		
Corrected Total	19	3450.607680			

Appendix 13(p). ANOVA for final weight (Finwt)

Source	DF	SS	MS	F Value	Pr > F
Treat	3	4321.022180	1440.340727	75.36	<.0001
Iniwt	1	2428.284831	2428.284831	127.06	<.0001
Error	15	286.675089	19.111673		
Corrected Total	19	7035.982100			

Appendix 13(q). ANOVA for feed conversion ratio (FCR)

Source	DF	SS	MS	F Value	Pr > F
Treat	3	149.0164150	49.6721383	49.90	<.0001
Iniwt	1	0.0240850	0.0240850	0.02	0.8785
Error	15	14.9323950	0.9954930		
Corrected Total	19	163.9728950			

Appendix 13(r). ANOVA for final girth (fingirthcm)

Source	DF	SS	MS	F Value	Pr > F
Treat	3	928.4672550	309.4890850	22.83	<.0001
Inigirth	1	397.6962123	397.6962123	29.34	<.0001
Error	15	203.355308	13.557021		
Corrected Total	19	1529.518775			

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