EFFECT OF SEASONALITY OF FEED RESOURCES ON DAIRY CATTLE PRODUCTION IN COASTAL LOWLANDS OF KENYA

A thesis submitted in fulfillment of requirements for Doctor of Philosophy Degree of University of Nairobi (Animal Nutrition).

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

To ***Irene Njeri***, my beloved wife and dear friend,

Lesley Kamwende, my daughter

and

Lewis Mburu, my son.

For their Love, Care, Support, Protection and Prayers.

May the Almighty God Bless Them Abundantly.

Amen.

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LIST OF ABBREVIATIONS AND ACRONYMS

AIBP:	Agro-Industrial By-Products
ASALS:	Arid and semi-arid Lands
ATPS:	African Technology Policy Studies Network
BW:	Body weight
CP:	Crude Protein
DM:	Dry Matter
EAAPP:	East African Agricultural Productivity Programme
GDP:	Gross Domestic Product
GoK:	Government of Kenya
HS:	Herd size
KNBS:	Kenya National Bureau of Statistics
KARI:	Kenya Agricultural Research Institute
MDMI:	Mean dry matter intake
MLWC:	Mean live weight change
MMP:	Mean milk production
NCFR:	Non-Conventional Feed Resources
NDDP:	National Dairy development Project
TLU:	Tropical Livestock Units

ABSTRACT

In the Coastal Lowlands of Kenya, small-scale integrated crop-livestock system is the dominant form of agricultural production. Feed quantity and quality are inadequate and rarely meets the nutrient demands of lactating cows especially, in the dry seasons. The objective of this study was to determine the effect of seasonality on availability and quality of feed resources on dairy cattle productivity in Coastal Lowlands of Kenya. A cross-sectional survey was conducted in Kwale and Kilifi counties on a random sample of 415 dairy cattle farms followed by a longitudinal survey on a purposive sample of 32 farms from the cross-sectional sample over a period of 12 months.

Data from the cross-sectional survey was analyzed for descriptive statistics. Two-Step cluster analysis was used to classify small-scale farmers using variables selected *apriori* and identified four distinct clusters. The validity and stability of the 4-clusters solution was tested by splitting the sample into two sub-samples according to counties and cluster analyzed separately using the variables selected *apriori*. Discriminant analysis was done using demographic and socio-economic variables not previously considered in the cluster procedure in order to ascertain the profile of each cluster. The mean herd size was 3.9 of which 30.7% were lactating cows. The mean milk yield/cow/day was 5.7 litres with 44% of farms producing < 5 litres/cow/day. The mean land size was 5.3 acres with 68.4% of households' having < 6 acres. For the whole sample, 30.4, 28.8, 20.6 and 20.2% of the households were classified into clusters 1, 2, 3 and 4 respectively. Each cluster had unique characteristics which would help define research and development policy priorities based on resource base, opportunities and constraints.

The mean CP and NDF of pasture grasses ranged from 84.1 - 97.1 and 603.8 - 724.8 g/kg DM respectively. *Leucaena leucocephala* had the highest CP of 270.8 g/kg DM. *Asystacia gangetica* and *Commelina benghalensis* had a CP content of 131.8 and 162.7 g/kg DM respectively. Napier grass had a CP of 86.4 g/kg DM. Maize stover and green maize forage had CP of 72.2 and 112.8 g/kg DM respectively. The mean CP of maize germ and maize bran was 104.4 and 129.3 g/kg DM with 33.5% and 24.6% utilization respectively.

A. gangetica, C. benghalensis, L. leucocephala and maize forage had higher *in vitro* DM digestibility (IVDMD) (> 50%) compared to maize stover, pastures grasses and napier grass. Pastures grasses IVDMD ranged from 40.3 - 44.7%. *In situ* rumen DM and CP disappearances were measured at 0, 6, 12, 24, 36, 48 and 72 hours of incubation using mobile nylon bag technique. The CP disappearance ranged from 16.81 - 23.54%, 9.91 -17.96%, 20.02%, 9.56%, 13.95% and 20.99% at zero time and 50.64 - 58.47%, 39.11 - 49.46%, 45.78%, 33.49%, 40.25% and 55.22% at 48 hours for weeds, pasture grasses napier grass, maize stover, green maize forage and *L. leucocephala* respectively. The potential degradability of DM ranged from 60.22 - 72.99% for weeds, 45.52 - 65.8% for pastures, 54.73% for maize stover, 82.24% for green maize forage, 64.16% for napier grass to 74.44% for *L. leucocephala*. Effective degradability (ED) of DM and CP decreased with increase in outflow rates of 2, 5 and 8% and differed significantly ($P < 0.05$) between roughages. The ED of DM ranged from 18.68 - 30.13% and 35.48 - 49.23% at outflow rates of k=8 and k=2 for *P. maximum* and *L. leucocephala* respectively. At the same outflow rates, the ED of CP ranged from 20.6 - 29.2% and 36.6 - 51.2% for the two.

Pastures grasses occupied 56.4% (414.5 ha) of land and contributed 55.2% of feed resource. Maize occupied 63.5% of cultivated land and yielded 430.1 mt DM/year of maize stover while napier grass occupied 29.3% and contributed 15.1% of basal feed resource. The estimated annual on-farm feed production and animal requirements was 3,865 and 5,004 mt DM respectively. The annual on-farm feed DM production met cattle requirements during April-June season only. The mean animal live weight change (MLWC) ranged from 168 to 268 g/day for season III (January-March) and season IV (April - June) respectively. The average milk production (AMP) ranged from 4.7 - 5.6 litres/cow/day for season III and season I respectively. Pooling all available feed resources for 12 months through appropriate storage and carry-over between seasons decreased MLWC from 268 to 257 g/day in season IV but increased from 264 to 274, 261 to 278 and 168 to 187 g/day in seasons I, II and III respectively. The AMP followed the same trend as MLWC, decreasing in season IV and increasing in seasons I, II and III. This showed that dairy cattle obtained enough nutrients only in season IV.

In conclusion, the crop-livestock production systems in study area were classified into four distinct clusters with distinct production characteristics. Productivity was low within all the clusters and was attributed to poor quality cows and inadequate forage whose availability was seasonal. The available forages were of moderate quality with average to high rumen degradability. There was a deficit in DM availability during the dry season which could be remedied through conserving excess feed during the wet season. These results could be used to develop an integrated forage production and livestock nutrition management plan to provide sufficient year-round feed supply based on animal requirements and supplementation strategies.

1.0: INTRODUCTION

1.1: Background

Livestock are the world's largest users of land, either directly through grazing or indirectly through consumption of fodder, crop residues and feed grains (Bruinsma, 2003). Globally, livestock are becoming agriculture's most important sub-sector as manifested by its growing contribution to satisfying increasing global and regional demand for high value products (Delgado *et al.,* 1999; Bruinsma, 2003). To increase animal productivity in order to satisfy these demands, agricultural policies advocate intensification of production, which requires enhanced external inputs and services (Devendra, 2001; Bebe *et al.,* 2002). The global drivers of the sector include economic growth and income, demographic and land use changes, dietary adjustments and technological change (Devendra, 2001; Steinfeld *et al.,* 2006). In the tropics animal production is dominated by the reliability and length of the wet season and this determines the nature of the animal production enterprise (Bakrie *et al*., 1996).

The livestock industry contributes to the Kenya economy through generation of tangible and intangible products and benefits and contributes 7% of the national GDP and 17% of agricultural GDP (GoK, 2010). Livestock serve as a means of livelihood and asset/wealth accumulation, income generation, employment and food for majority of rural households (Bruinsma, 2003). They also contribute to the sustainability of mixed crop-livestock production systems (Lekasi *et al.,* 2001; Schiere *et al*., 2002). This is achieved through recycling nutrients, increasing the availability of existing nutrients (with manure) and enabling the storing of nutrients until needed through the storing and composting of manure (Delve *et al*., 2001; Lekasi *et al.,* 2001). Estimates show that 53% of the rural poor keep livestock which are often the main means for income generation and about 28% of income of the richest 20% and about 61% of the income of the poorest 20% of rural households comes from livestock in Kenya (Thornton *et al*., 2002).

Dairy production is a major contributor to Kenya's livestock sector and an important source of livelihood for rural households comprising of more than 600,000 small-scale dairy farms scattered around the country (Omore *et al*., 1996). More recent estimates place the number of small-scale dairy farms at 1.8 million due to the increase in the Kenyan population (SDP, 2005). With an average national family size of about six persons (K.N.B.S, 2010), the sector supports nearly 10 million Kenyans from milk sales. These small-scale farmers practice mixed crop-livestock production systems, of which the dairy cattle constitute an integral component. They own over 80% of the total national dairy herd and produce about 70% of the total national milk output (Omore *et al.*, 1999; GoK, 2010). They own 1-3 cattle and market milk through a dualistic system either through processors or informal channels directly to consumers, traders or through cooperatives (Omore *et al.*, 1999; Muriuki *et al.*, 2003).

The major constraint to dairy production in Kenya is poor nutrition due to scarcity of feeds (Muriuki *et al*., 2003; GoK, 2010; Salami *et al*., 2010). As a result, animals suffer severe nutritional stresses which often lead to low calving rate, low birth weight, high calf mortality, reduced mature body size, low growth rate, delayed maturity and more importantly low milk production (Omore *et al*., 1996; Lanyasunya *et al*., 1999; Muinga *et al.*, 1999). In the coastal region of Kenya, forage productivity is largely dependent on rainfall (Mureithi *et al.,* 1998; Muinga *et al.*, 1999) which, is highly variable and often unpredictable (Jaetzold and Schmidt, 1983). The situation is further compounded by decreasing farm sizes (K.N.B.S, 2010). As a result, forage biomass yield, quality and availability varies substantially from season to season.

Seasonal fluctuations in feed supply have been identified as a major constraint to milk production in coastal region (Muinga *et al.*, 1999; Nicholson *et al*., 1999). During the rainy season, forages are often in excess supply and average milk production ranges from 10 - 15 litres/cow/day and inadequate during the dry spell leading to a decrease in milk production to about 5 - 6 litres/cow/day (Muinga *et al.*, 1999). However, opportunities exist for dairy cattle development in the region due to high demand for milk and other dairy products. This created a need to develop strategies to synchronize feed availability with the nutritional requirements of dairy cattle throughout the year in the Coastal Lowlands of Kenya.

1.2: Statement of the Problem

The major constraint to dairy cattle production in Kenya has been reported to be poor nutrition (Omore *et al*., 1996; Muriuki *et al*., 2003; GoK, 2010; Salami *et al*., 2010). Feed quantity and quality are inadequate and rarely meet the nutrient demands of lactating dairy cows, especially during the dry season in coastal region (Nicholson *et al*., 1999; Ramadhan *et al.*, 2008; Muinga *et al.*, 1999). This inadequacy is mostly related to seasonality of feed supply due to dependence on precipitation for forage production. The availability of good quality natural pastures and cultivated fodders dwindles during the dry season with farmers using crop residues as the main source of dairy cattle feed. However, utilization of crop residues is limited due to their poor quality which is too low to support satisfactory milk production and reproduction (Muinga *et al*., 1999).

Ideally, dairy feed rations should be balanced in all nutrients (protein, energy, minerals, vitamins and water) to enable the cow meet its daily nutrient requirements. In addition, there exists a paucity of information on temporal and spatial availability of feeds necessary for development of feeding options which would synchronize potential nutrients supply with the requirements of animals throughout the year. As a result farmers' efforts to improve dairy cattle productivity is constrained by inadequate information on the distribution of forage biomass quality and availability as it varies from season to season. This study aimed to characterize the crop-livestock production systems; identify available feed resources, evaluate nutritive value, determine rumen degradation kinetics of common roughages; estimate dry matter yields, estimate animal dry matter intake and nutrient requirements during different seasons in dairy farms in Coastal Lowlands of Kenya.

1.3: Justification of the Study

Livestock plays an important economic and socio-cultural role among Coastal Lowlands of Kenya. In the region, milk and milk products enjoy a strong demand with about 45% of the milk consumption coming from other parts of Kenya. Farm forage production is rain-fed and dairy cattle requirements vary over the year depending on the type of forage, rainfall variability and livestock management used. This leads to reduced milk yield, especially during the dry months and limits development of commercial milk production, despite the strong local demand for milk and milk products. Therefore, the reasons for research on the effects of seasonality of feed resources on small-scale dairy cattle production in Coastal Lowlands of Kenya was concerned with improving milk production and hence incomes of farmers. An analysis of feed resources production and distribution in rainy and dry seasons will provide a detailed assessment of the supply and demand situation for different feed types for livestock over the year. These results could be used to develop an integrated forage production and livestock nutrition management plan to provide sufficient year-round feed supply based on requirements and supplementation strategies. This plan should provide a year-round forage supply in the quantity and quality needed by the livestock, as inexpensively as possible. Upscaling such information will allow for interventions tailored to small-scale dairy farmers' in specific agro-ecological zones conditions. In addition, there is good potential for increased milk demand and farm level prices due to increasing human population. Dairy cattle production can lead to increased employment opportunities in the area both directly through on-farm engagement of household members, casual and long-term labourers and indirectly through supply of inputs and milk traders. Dairying can have positive impacts on soil fertility maintenance in intensive mixed cropping systems, a role that may grow with intensification. Finally, these results were expected to stimulate a demand and acquisition of dairy grade cattle genotypes from small-scale farmers for improved milk productivity and subsequent income from sales of milk and other by-products leading to agricultural development.

1.4: Objectives

1.4.1: Overall Objective

The overall objective of the study was to determine the effects of seasonality of feed resources on dairy cattle production in Coastal Lowlands of Kenya.

1.4.2: Specific Objectives

The specific objectives of the study were to:

(i) Characterize crop-livestock production systems in small-scale dairy cattle farms in Coastal Lowlands of Kenya.

(ii) Evaluate chemical composition of common feedstuffs in small-scale dairy cattle farms in Coastal Lowlands of Kenya.

(iii) Determine rumen degradation kinetics of common feedstuffs in small-scale dairy cattle farms in Coastal Lowlands of Kenya.

(iv) Determine forage dry matter production and dairy cattle requirements in small-scale farms in Coastal Lowlands of Kenya.

1.5: Null Hypotheses

(i) The crop-livestock production systems do not vary in small-scale dairy cattle farms in Coastal Lowlands of Kenya.

(ii) The chemical composition of common feedstuffs in small-scale dairy cattle farms do not vary in Coastal Lowlands of Kenya.

(iii) The rumen degradation kinetics of common feedstuffs do not vary in small-scale dairy cattle farms in Coastal Lowlands of Kenya.

(iv) The forage dry matter production and dairy cattle requirements do not vary in small-scale farms in Coastal Lowlands of Kenya.

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2.0: LITERATURE REVIEW

2.1: Kenya Livestock Industry

Kenya has a total land area of approximately 581,313 km^2 with a population of 38.6 million persons (KNBS, 2010a). The country has a wide range of vegetation cover ranging from patchy grass cover in the arid areas to woodlands in the high rainfall areas. There are also considerable variations in soil types with most soils having low fertility. The altitude ranges from 0 to 3,000 metres above sea level which gives rise to wide variations in rainfall and temperatures. The average annual rainfall ranges from 250 to 2,500mm while temperatures range from less than 10^oC to 30^oC (Jaetzold and Schmidt 1983a, b, c). The areas categorized as medium and high agricultural potential areas receive 750 to 2,500mm of rainfall annually and constitute about 17% of total land area. The rest of the country consists of low agricultural potential arid and semi-arid lands which cannot reliably support rain-fed agriculture (Sombroek *et al*., 1982).

Agriculture is one of the key sectors in the country with great potential for growth and contributes about 26% of the Gross Domestic Product (GDP), 75% of industrial raw materials and 65% of the export earnings (GoK, 2010). It's also acknowledged as one of the major employers of rural people. The livestock subsector contributes 7% of the GDP and 17% of agricultural GDP. In arid and semi-arid lands (ASALS) livestock production accounts nearly 90% of the employment opportunities and nearly 95% of the family incomes (Thornton *et al.*, 2002; GoK, 2008). The small-scale farming, more common in the higher potential areas, accounts for 75% of total agricultural production and 70% of marketed agricultural produce (GoK, 2010). These small-scale farmers own 2-3 hectares and production is mainly for subsistence.

In Kenya, livestock have been kept by the different communities for centuries and they remain an important sub-sector of agriculture to achieve multiple objectives. They have important social functions; provide multiple products for both subsistence and income generation, such as meat, eggs, milk and fibres while dung and urine are valuable for fertilizing gardens, fields and fish ponds (Lekasi *et al.,* 2001; Bruinsma, 2003). They are also a form of savings or collateral, income diversification and risk reduction to producer households and rural communities (Udo and Corneliseen, 1998; Thornton *et al*., 2002; GoK, 2004). Animals also utilize products that are not exploited by humans: kitchen wastes, grass from roadsides and wastelands and crop residues as feed (McIntire *et al*., 1992; Lekasi *et al*., 2001). Livestock in semi-arid eastern Kenya have traditionally been a means of raising cash when needed (Simpson *et al.,* 1996) in addition to providing meat, milk, manure and draft power. It's an alternative enterprise that offers higher returns, has the potential for future growth, and is suitable for poor small-scale farmers who dominate agricultural production in marginal zones (Nicholson *et al*., 2004).

The country has a large and diverse livestock resource base estimated to be over 99 million (Appendix 7.1). They comprise 20.2 million indigenous chicken, 6.1 million commercial chicken (layers and broilers), 17.5 million cattle (indigenous, exotic and cross breeds), 27.7 million goats (dairy and meat), 17.1 million sheep (wool and hair), 2.9 million camels, 1.8 million donkeys and 334,600 pigs (KNBS, 2010b). They utilize 3,240,000 ha, which is 47.4% of the total land utilized for agricultural production (Sombroek *et al*., 1982). Livestock are kept in all parts of the country either under the pastoral extensive system in the arid and semi-arid lands or under more intensive ranching and small-scale systems (GoK, 2008). Of the 17.5 million cattle, it's estimated that 3.4 million are exotic breeds mostly owned by small-scale farmers and 14.1

million are indigenous breeds (ATPS, 2013). However, the proportion of dairy cattle varies widely across agro- ecological zones since the profitability of dairying differs, but also within agro- ecological zones.

The Nyanza Province had the highest concentration of cattle (139/km^2), although the largest number of 7.5 million was found in Rift valley Province. Coast province had the lowest density of 12 cattle /km^2 (KNBS, 2010b). The high-potential highland areas, where temperature is moderated by altitude, receive a greater and more reliable rainfall than medium-potential areas that are predominantly found at lower altitudes (Jaetzold and Schmidt 1983a, b, c) which largely explains the current skewed distribution of dairy cattle in favour of these areas (KNBS, 2010b) as forage production is related to rainfall, disease risk is reduced at higher altitudes and demand for milk is high from the dense population located in the highlands (Staal *et al*., 2001).

2.1.1: The Kenya Dairy Industry

Dairy farming is a key component of livestock industry in Kenya and is dominated by *Bos taurus* dairy breeds/genotypes (DBG) comprising Friesian, Ayrshire, Guernsey, Jersey and crosses among themselves (Muriuki *et al*., 2004). It is a major activity in Kenya's livestock sector and is an important source of livelihood to many Kenyans and contributes approximately 4% of Kenya's GDP (GoK, 2010). It acts as a source of income and employment to over one million small-scale dairy farmers who account for 56% of the total milk production and 70% of the total marketed milk in the country (SDP, 2005, USAID Kenya, 2009, GoK, 2010).

The Kenya dairy industry dates back to the 1920's when it was dominated by large-scale farms (Jahnke, 1982) based on high-grade cattle introduced into the Kenya Highlands by the European settlers (Conelly, 1998). In 1954, the Swynnerton Plan advocated for the development of African small-scale farming, especially cash crops and improved livestock breeds (Swynnerton, 1954). Although small-scale Kenyan farmers were entitled to keep dairy animals under certain conditions, they usually lacked the needed cash to engage in dairying (Conelly, 1998). Notwithstanding the foregoing, progressive transfers of ownership of grade cattle to small-scale Kenyan farmers started before independence in 1963. Soon after independence in 1963, government policy to support small-scale farmers marked the beginning of small-scale domination of the dairy industry (Muriuki *et al.,* 2004). Dairy production has slowed in growth as manifested in milk production which has decreased from 4,050,750 mt in 2011 to 3,750,000 mt in 2013 (FAO, 2014).

The small-scale dairy farming systems are socially dynamic, economically and technologically diverse and own 80% of the cattle in Kenya (Bebe *et al.*, 2002). This diversity stems from differences in agro-ecological conditions, population densities, socio-economic activities and institutional changes (Dixon *et al.,* 2001). Feeds vary from purposely grown fodder crops such as napier grass, legumes, tree shrubs such as *Leucaena leucocephala* to crop residues such as maize stover and mixed pasture grasses which are either grazed or cut for stall feeding (Maarse *et al*., 1990; Reynolds *et al*., 1993; Mureithi *et al.*, 1998). However, growth in milk production by small-scale farmers has been slow mostly due to technical constraints and feed scarcity (Omore *et al*., 1996; Muriuki *et al*.,, 2003; GoK, 2004; Salami *et al*., 2010). Additionally, the farmers are known to be resource poor and often operate below their potentials (Nyikal, 2000).

2.1.2: Kenya Coastal Region Small-scale Dairy Sub-sector

Kenya Coastal region consisting of Kwale, Kilifi, Mombasa, Lamu, Tana River and Taita Taveta counties (Table 1) covers about 82,000 km^2 in the south-eastern part of Kenya, constituting about 14.3% of the country's land area (Jaetzold and Schmidt, 1983c; KNBS, 2010a). It has a population of 3,325,307 inhabitants, or about 9% of Kenya's total population of 38.6 million (KNBS, 2010a).

Table 1: Cattle population in the coastal region of Kenya by county and density

County	Cattle	Land area (km^2)	Density (number of households /km^2)	Density (number of cattle /km^2)
Mombasa	12,997	218.8	4,319	59
Kwale	255,143	8,270.1	96	31
Kilifi	186,963	12,609.7	150	15
Tana River	269,894	38,436.9	6	7
Lamu	81,200	6,273.1	16	13
Taita Taveta	153,768	17,084.1	18	9
Total	**959,965**	**82,892.7**	**40**	**12**

Source: KNBS (2010b)

The coastal region has a large and diverse livestock resource base comprising 1.6 million indigenous chicken, 0.5 million commercial chicken (layers and broilers), 1 million cattle (indigenous, exotic and cross breeds), 1.6 million goats (dairy and meat), 0.5 million sheep (wool and hair), 51,045 camels, 31,916 donkeys and 5,243 pigs (Appendix 7.1). The highest number of cattle per area were found in Mombasa county at 59/km^2 followed by Kwale County and Kilifi County at 31 and 15 cattle/ km^2 respectively (Table 1).

The most commonly used classification scheme defines the region's agro-eco zones based on mean annual rainfall, temperature and soil type (Jaetzold and Schmidt, 1983c). Much of the region is classified as Coastal Lowland (CL) zones (Figure 1). The zonation corresponds with rainfall gradients and indicates the possibilities of growing certain crops and rearing livestock. Annual rainfall is highest in CL3 (1000 mm per year), lower in CL4 (900 mm per year), and lowest in CL5 (700 - 900 mm per year).

The CL zones are subdivided into the Coconut-Cassava zone (CL3), Coconut-Cashew zone (CL4), and Livestock-Millet zone (CL5) as shown in Figure 1.

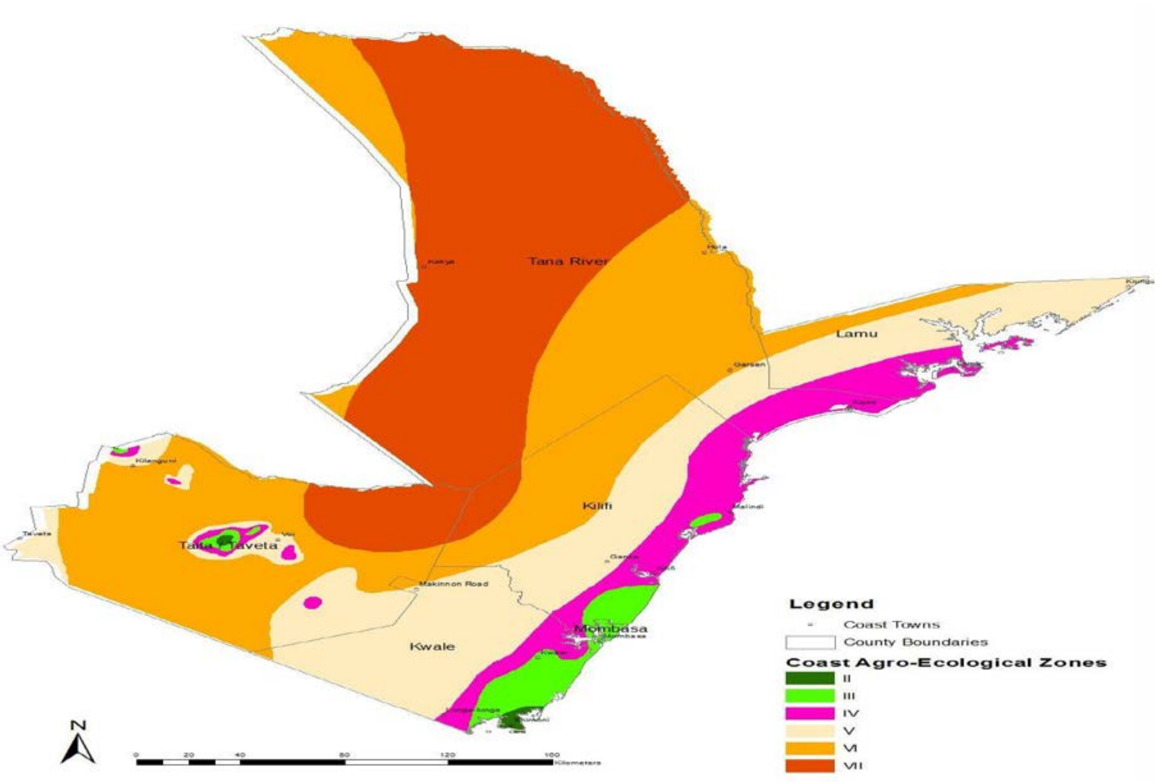

Figure 1: Coast region agro-ecological zones (Source: Jaetzold and Schmidt, 1983c)

The coastal strip and the higher Taita Taveta and Shimba hills receive the highest rainfall of between 1200 - 1600 mm/year. The lowest rainfall range is 200-400 mm/year in the North of

Tana River County and the Tsavo National Park which is in Taita Taveta County (Jaetzold and Schmidt, 1983c). The rainfall is bi-modal, with the long rains between April and June and the short rains from October to December. The short rains come in October and November decreasing rapidly to a minimum in Months of January and February. The annual rainfall pattern is influenced by the Monsoon winds with the main rains coming between late March and early June and decreasing from August.

Kenya's coastal region agricultural potential is relatively low due to limited amount of precipitation, high level of rainfall variability and lack of fertile soils (Jaetzold and Schmidt, 1983c; Sombroek *et al*., 1982). The amount of rainfall has a high impact on land capability classification as it determines the type of activity that can be undertaken in an area as well as its potential (Jaetzold and Schmidt, 1983c). A variety of production systems are employed by small-scale dairy farmers in the coastal region, ranging from stall-fed cut-and-carry systems supplemented with purchased concentrate feed in areas of high population density, to free grazing on unimproved natural pasture in the more marginal areas (Danda *et al*., 2002). Exotic dairy breeds tend to be kept in stall-feeding units, while free-grazing dairy animals are more likely to be cross-bred cattle (Bebe *et al*., 2002).

In Coast province, dairy cattle production was enhanced when the National Dairy Development Project (NDDP) supported by the Dutch and Kenyan government was started in 1980 in 6 districts among them Kilifi district (now the Kilifi County) (NDDP, 1992a). The project advocated and emphasized on zero grazing and the growing of at least one acre of Napier grass *(Pennisetum purpureum*) per cow as the primary forage source. The coast region of Kenya, despite the attention from the NDDP and other development agencies has over the year's registered low growth in both the dairy cattle population and milk production (Thorpe *et al*., 1993). This contrasts with the highlands, where small-scale dairy production contributes the major proportion of marketed milk (Omore *et al*., 1999).

Comprehensive studies on adoption of modern dairy technologies in the Coast province were done in the 1990's (NDDP, 1992a; Nicholson *et al.,* 1999). The main focus was on napier grass, dairy cattle and disease control. An adoption and impact study by Nicholson *et al*. (1999) reported that 50% of households in coastal Kenya had adopted grade cross cattle during the period between 1974 and 1996. A study conducted in Kilifi County on the distribution of labour in the dairy sub-sector indicated that women performed 30% of dairy activities, men 20%, hired labour 18%, children 26% and others 6% (NDDP, 1992b).

2.2: Limitations to Dairy Cattle Production in Coastal Region of Kenya

Kenya's dairy development exemplifies intensification through adoption of improved small-scale dairy cattle production technologies such zero-grazing (Bebe *et al*., 2002) and fodder production practices (Mambo *et al.,* 2004). Zero-grazing is widespread in coastal lowlands (Ramadhan *et al*., 2008) where landholdings are continuously decreasing due to intergenerational sub-division for inheritance driven by rapid growth in human population (KNBS, 2010a). In the coast province, the population rose from 944,082 to 3,325,307 persons from 1969 to 2009 which translates to an increase from 1.6 to 5.7 persons/ km^2 respectively. Growth in milk production by small-scale farmers has lagged behind demand mostly due to technical constraints (Muriuki *et al*., 2003; GoK, 2010; Salami *et al*., 2010). Other important factors that influence dairy development, besides animal management related issues, include poor and inadequate infrastructure. However, some of these challenges are being addressed through efforts outlined in the Dairy Master Plan (GoK, 2010).

Livestock production and productivity is affected by numerous factors and range from climate, nutrition and health aspects (Lamy *et al*., 2012). Cimatic changes are accompanied by more changes in the productivity (quantity and quality) of rain-fed crops and forage, reduced water availability and more widespread water shortages, changing severity and distribution of important human, livestock and crop diseases (ATPS, 2013). Low rates of dairy cow ownership have been attributed to the susceptibility of these animals to diseases common at the coast, particularly tick-borne diseases such as East Coast Fever (theileriosis), anaplasmosis, and babesiosis (Nicholson *et al*., 1999). In the coast, Theileriosis results in an annual mortality rate for dairy cows of about 30% (Maloo *et al*., 1994). Trypanosomosis carried by the tsetse fly is another important health problem for small-scale farmers, particularly in Kwale County (Maloo *et al*., 1994). In addition, seasonal shortages of feed for dairy cows have been identified as a major constraint (Muinga *et al.,* 1999). Protein and energy availability are nutritional factors likely to limit milk production in coast region (Muinga, 1992).

The relative monthly rainfall and forage availability in the coastal region varied as shown in Figure 2. The rainy seasons are associated with high biomass production and animals are fed on a variety of feeds, including weeds from the arable land while the planted forages are spared for the dry season (Muinga *et al*., 1999; Mureithi *et al.*, 1998). During the dry season the availability of good quality natural pastures and/or cultivated fodders decrease and during these times low quality crop residues such as maize stovers contribute the bulk of feeds for cattle. Utilization of maize stovers is constrained by the low crude protein concentration (Nicholson, 1984; Little and Said 1987). Most dairy cattle in coastal lowlands rely on natural pastures as the main feed source (Reynolds *et al*., 1993; Mureithi *et al*., 1998) under the free grazing system (Muinga *et al*., 1999). Feed quantity and quality are inadequate and rarely meet the nutrient demands of a lactating dairy cow, especially in the dry season (Reynolds *et al*., 1993; Nicholson *et al*., 1999). The available feeds are thus inadequate in quality and quantity to meet the year-round requirements of animals (Reynolds *et al.*, 1993; Muinga *et al.*, 1999; Ramadhan *et al.*, 2008).

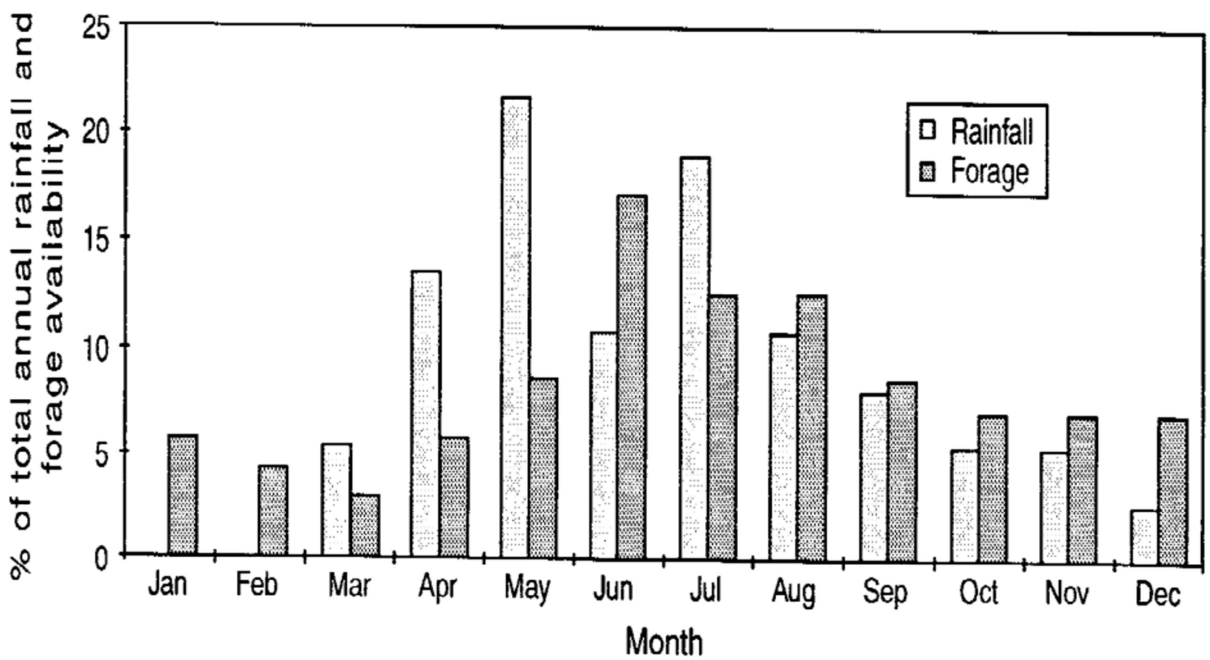

Figure 2: Relative monthly rainfall and forage availability in Coastal Lowlands of Kenya (Source: Mureithi *et al*. 1998)

In coastal lowlands small-scale farmers have limited resources to invest in feeding their ruminant livestock when amount of pasture is low (Muinga, 1992; Abdulrazak, 1995) probably due to low level of commercialization. The use of commercial concentrates is thus not common among the small-scale dairy farmers as only a few buy sufficient quantities for feeding their dairy cows

(Valk, 1990; Muinga, 1992; Thorpe *et al*., 1993). This has constrained development of commercial milk production inspite of a very strong local demand for milk (Thorpe *et al*., 1993). The greatest shortage of feed is experienced from January to March, especially if the short rains fail, when dairy cows are fed on poor quality by-products such as maize stover, mango leaves and dry grass from fallow land (Muinga *et al.*, 1999). The resulting nutritional stress leads to decreased productivity expressed through low calving rate, low birth weight, high calf mortality, low weaning weight, reduced mature body size, low growth rate, delayed maturity and more importantly, low milk production (Muinga *et al.*, 1999; Wanjala and Njehia, 2014).

2.2.1: Factors Affecting Feed Intake

The spectrum of factors that affect voluntary feed intake by animals is very broad. A review of literature on factors that affect forage voluntary intake by ruminants has been done by various authors (Montgomery and Baumgardt, 1965; Conrad, 1966; Allison, 1985). Montgomery and Baumgardt, (1965) showed the relationship of the nutritive value of feed and feed intake to factors limiting feed intake (Figure 3). In summary, it can be stated that a ruminant animal's dry matter intake is affected by feed factors (the quality and availability of forage and the amount and type of supplements); the environment factors like heat stress (Morton, 2007) and the animal itself (including size, body condition, stage of life and level of production) (NRC, 2001). Ambient temperature has the greatest direct effect while feed intake has the greatest indirect effect on dairy cattle performance (McManus *et al*., 2005).

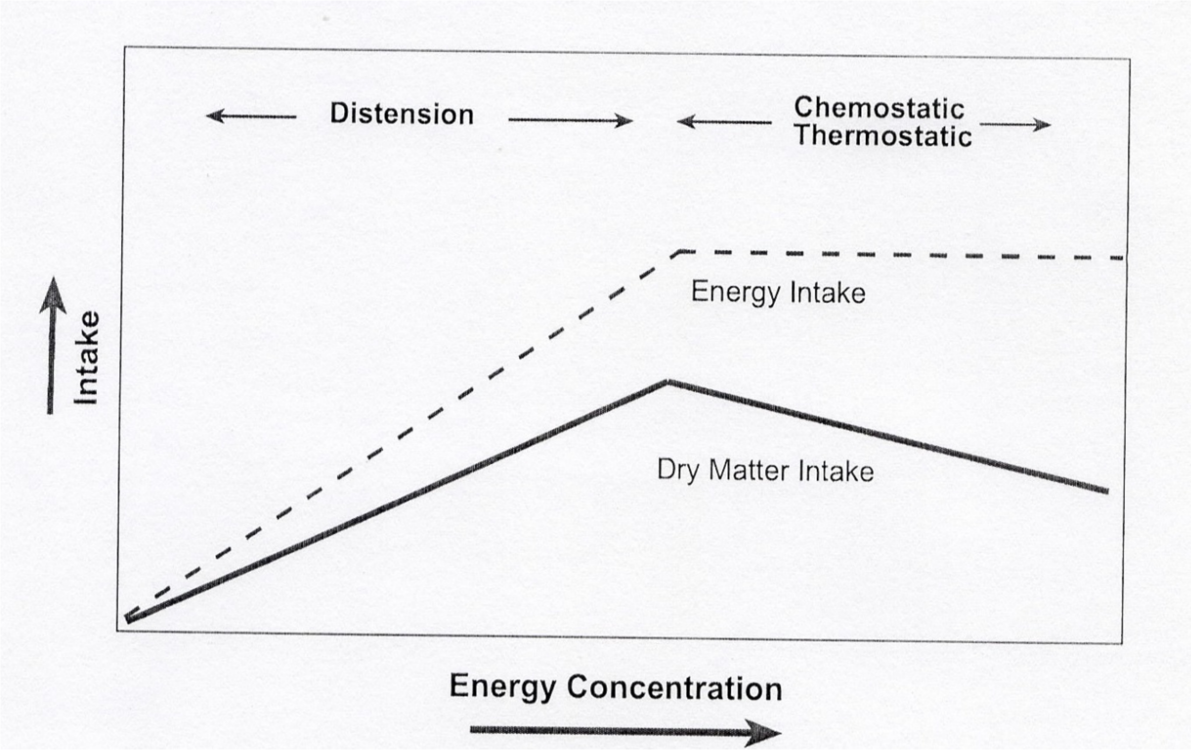

Figure 3: The relationship of the nutritive value of feed and feed intake to factors limiting feed intake. Adapted from Montgomery and Baumgardt (1965).

Quality of forage offered to the animals has been reported to influence rate and extent of *in situ* digestion thus affecting intake (Van Keuren and Heinemann, 1962; Hopson *et al*., 1963; Vanzant *et al.*, 1996). Feed nutrient content and nutrient balance is an important determinant of its intake. Feed quality and physical characteristics of forage, such as a dry matter (DM) content, fibre content, particle size, and resistance to fracture are known to affect ease of prehension and thus intake rate (Inoue *et al.*, 1994). Apart from energy, controlling balances for specific nutrient groups (carbohydrates, fat, and protein) might influence voluntary feed intake as well (Revell and Williams, 1993). Lignin and fibre contents in vegetation also affect intake (Papachristou *et al.*, 2005).

Of particular relevance is the prediction of the animal's intake, an important aspect related to feeding forages which is influenced by digestible DM and CP content and extent of degradation (Minson, 1990). However, in practice, the prediction of the roughage intake still presents problems (Blümmel and Becker, 1997). Variation in forage quality can impact dry matter (DM) intake, diet energy density, dietary grain and protein supplementation amounts, feed costs, lactation performance, and cow health. Forage quality is highly variable among and within forage types (NRC, 2001). Forage species, variety or hybrid, stage of maturity at harvest, cutting, environmental factors, production and harvest practices, storage method, and ensiling practices all are factors that contribute to this variation (Shaver *et al*., 2002).

2.3: Chemical Composition and Digestibility

2.3.1: Chemical Composition

Forage quality may be defined as the type and amount of digestible nutrients available to the animal per unit time (Barnes and Marten, 1979) and is highly variable among and within forage types (NRC, 2001). An adequate dietary analysis of any sort requires that the methods employed are relevant to a nutritional classification of the dietary chemical components (Van Soest and Robertson, 1985). Feed evaluation needs to define roughage characteristics which determine animal performance, for example live-weight gain and milk yield (Blümmel *et al*., 1997). The chemical composition and digestibility of forages are influenced by plant species, plant morphological fractions, environmental factors and stage of maturity (Papachristou and Papanastasis, 1994). Improvements in the methods of feed evaluation have followed new concepts in chemistry, animal physiology, rumen microbiology knowledge and related fields of science (Flatt, 1988).

The nutrition of domesticated ruminants in arid and semiarid regions in the tropics has been a problem for farmers due to lack of basal feeds (Hernandez *et al*. 1998). Nutritional inadequacy limits the performance of animals especially during the dry season when the quality and quantity of the natural pasture declines (Minae and Nyamae, 1988; Muinga *et al.*, 1999). In semi-arid regions, grasses are more abundant than legumes and form the major feed for livestock. They are of low quality (2 - 4% CP) for most of the year (Thairu and Tessema, 1987) especially after post flowering stage. Further, they contain high fibre and are poorly digested by animals. Leng (1990) defined low quality forage as those with CP of less than 8% and suggested supplementation of such forages with appropriate nutrients to achieve high levels of animal production.

Feed quality and quantity have been identified as the major constraints to dairy production especially during the dry season in the coastal region (Muinga *et al.*, 1999). Most dairy farmers rely on natural pastures from the farm or cut and carry to the animals from roadsides and fallow land off-farm and crop residues (Mureithi *et al*., 1998). These pastures and crop residues are of variable quality and in cases of severe droughts may not be available (Abdulrazak, 1995). When available even in limited quantities, the fibrous feeds such as cereal crop residues and poor quality mature grasses cannot maintain animals during much of the year (Muinga *et al.*, 1999). They are of low nutritive value due to their low digestibility and failure to provide the rumen microorganisms and the host animal with all the nutrients required (Preston, 1986; Undi *et al*., 2001).

The data summarized in Table 2 shows chemical composition of common forages in the coastal region. Maize stover is a common crop residue in the area and is characterized by low nitrogen

(< 3% CP) and over 70% NDF) (Urio and Kategile, 1987; Juma *et al*., 2006). *Commelina diffusa*, also common in the area, contained 177 g crude protein (CP)/kg dry matter (DM) (Lanyasunya *et al.*, 2006). *Leucaena leucocephala* had CP content of 23.7% while that of natural pastures was 3.4% in coastal region (Njarui *et al*., 2003).

Table 2: Chemical composition (g/kg DM) of common forages in coastal region

Roughage	DM	CP	NDF	ADF	References
Napier grass	na	46.3	721.4	457.7	Njarui *et al*., 2003
	na	90	706	436	Abate and Abate, 1991
	176	76	753	na	Abdulrazak *et al*., 1996
	na	11.6	72.68	na	Munga *et al*., 2014
	na	64	690	na	Muinga *et al*., 1995
L. leucocephala	300	218	469	na	Abdulrazak *et al*., 1996
	310	225	394	na	Abdulrazak *et al*., 1997
	na	237.3	339	159.2	Njarui *et al*., 2003
Maize stover	642	52	784	481	Juma *et al*., 2006
	863	29	768	na	Abdulrazak *et al*., 1997
Mixed pastures	na	33.8	766.1	541.4	Njarui *et al*., 2003

na – no figures available.

Napier grass, common during the wet season, has low nutritive value and may not meet the animal production requirements throughout the year (Muinga *et al*., 1999). It contains low to moderate crude protein (CP) content (6 - 12%) during the wet season, but declines to less than 5% during the dry period (*Njarui et al*., 2003; Juma *et al*., 2006). Below a critical level of 6 - 8% CP in cattle diet, digestibility and voluntary intake of forage are likely to be reduced (Humphreys, 1991). In addition, the digestibility of forages in the rumen is related to the proportion and extent of lignification (Van Soest, 1994). Under cut-and-carry forage feeding systems in small-scale animal production systems, leaves and twigs are commonly used as feed for small ruminants, especially during the dry season (Karachi, 1998).

2.3.2: Digestibility

Methods of estimating forage digestibility are based on: (1) empirical relationships between forage fibre and digestibility (Rohweder *et al*., 1978); (2) Summative equations (Weis, 1994); (3) *in vitro* digestion of forages (Tilley and Terry, 1963; Menke *et al.*, 1979; Menke and Steingrass, 1988) or (4) *in vivo* and *in situ* evaluations (Ørskov and McDonald, 1979, Kempton, 1980). Each technique has its own limitations and weak points, and all the different sources of variation must be taken in account, as the alternative methods do not necessarily predict the same digestibility or even rank forages in the same order (Broderick and Cochran, 2000). The most accurate and precise approach is by feeding trials (*in vivo* studies) which are the 'gold standard' by which alternative methods are compared. However, because of the obvious limitations of expense, time and labour, *in vivo* studies are not practical as a routine analysis. This has led to increased interest in using *in vitro* and *in situ* techniques (Broderick and Cochran, 2000).

The quality of rumen fluid represents a common source of variation of *in vivo*, *in situ* and *in vitro* techniques (Mould *et al.,* 2005). The quality of rumen fluid, in terms of number and kind of microbial population, is mostly influenced by diet composition (Bryant and Burkey, 1953; Makir and Foster, 1957) and by feeding frequency (Thorley *et al*., 1968). There is still a wide variation in the results of *situ* experiments obtained in different laboratories, with the main sources of variation coming from: basal diet, type of samples and animals, replication, incubation conditions, washing technique and correction for microbial contamination (Vanzant *et al.,* 1998; Broderick and Cochran, 2000). In addition, both *in situ* and *in vitro* determinations are expensive, rendering these techniques impractical for routine analyses (De Figueiredo *et al*., 2000).

2.3.2.1: Empirical Approach

In empirical relationships, the energy value of forages (i.e. forage quality) is a function of its digestibility and intake potential (Weis, 1994). As the concentration of forage fibre increases, intake potential and digestible energy concentration decrease. Environmental factors in which the forage was grown (temperature, moisture, and light intensity), cutting frequency and year affect the relationship between forage fibre and digestibility **(**Stallings *et al*., 1991**).** Even under the best conditions, the correlation between fibre levels of alfalfa and grass/legume mixtures to dry matter digestibility are typically 0.8 or less (Weis, 1994). Forage digestibility is most commonly predicted from a regression equation based on ADF where DDM = 88.7 - 0.779*ADF (Rohweder *et al*., 1978): where: ADF is Acid Detergent Fibre and DDM is Digestible Dry Matter.

2.3.2.2: Summative Equations

Summative equations provides alternative approach for predicting forage digestibility by analyzing forages for energy yielding components (i.e. the protein, fat, non-structural carbohydrate and fibre) and sum the digestible parts of each component together to predict forage digestibility (Weis, 1994). To calculate forage digestibility, total fibre (NDF), lignin (ADL), total protein (CP), cell wall bound protein (ADIN), fat, and ash contents of feeds are determined. Forages are analyzed for each nutrient by either wet chemistry or Near Infra Red Spectroscopy (NIRS) where each energy yielding component of the feed (fibre, protein, fat) is then multiplied by a digestibility coefficient and the products are summed together. Therefore, the summative method can be used to predict energy values of grass, legumes, corn silage and mixtures of forages (Weis, 1994). The disadvantages with this procedure are cost and time associated with analyzing the components.

2.3.2.3: In Vitro Digestibility Method

The *in vitro* techniques can be classified as: i) methods which measure the digestibility of feeds (Tilley and Terry, 1963); ii) methods which measure gas production from feed fermentation (Menke *et al*., 1979; Menke and Steingrass, 1988). Direct measurements of forage digestion by *in vitro* methods (Tilley and Terry, 1963) are more accurate and precise than the empirical approach (Mertens, 1993; Weis, 1998). Rate and extent of forage digestion can then be estimated by plotting the disappearance of forage over time (Ørskov and McDonald, 1979). According to Ørskov and McDonald, (1979) the forage dry matter is classified into three parts according to its digestion characteristics: soluble-instantly digested dry matter or cell solubles (fraction a); slowly digested NDF (fraction b); and indigestible NDF (fraction c). Fraction b is also defined by its rate (kd) of degradation.

In vitro ruminal digestion is estimated through incubation with ruminal microorganisms (ruminal *in vitro* methods) or cell-free enzymes (non-ruminal *in vitro* methods where protein degradation rate is measured from the rate of accumulation of amino acids and ammonia) which represent the products of protein degradation (Schwab *et al.*, 2003). The ruminal *in vitro* method uses ruminal digesta usually obtained from cannulated animals and the non-ruminal *in vitro* methods are based on the use of commercially available enzymes, with the intention of obtaining a result similar to that found in the rumen fluid (Broderick and Cochran, 2000). When rumen fluid is taken from intact cows, the greatest challenge is to achieve a representative sample in terms of microbial population and concentration (Mould *et al.,* 2005). In addition, there is a release of amino acids and ammonia from the microbial catabolism and the residual protein present in the inoculum, which leads to an overestimation of the degradation. This underestimation may be controlled by the use of a “blank” (Madrid *et al.,* 2002).

Menke and Steingrass (1988) developed the *in vitro* gas production technique to evaluate the nutritive value of forages andto estimate the rate and extent of DM degradation indirectly using the gas production (CO_2) during fermentation. Application of models allows fermentation characteristics of the soluble and readily degradable fraction of the feeds and the insoluble but slowly degradable fraction to be described. The technique has been used to assess biological values of feeds based on their pattern of accumulated gas when incubated with rumen fluid under anaerobic conditions. The volume of gas produced reflects the end result of the fermentation of the feed substrate to volatile fatty acids (VFAs), microbial biomass and the neutralization of VFAs produced (Getachew *et al*., 1998).

The gas production methods are less animal dependent; more appropriate for characterizing soluble or small particulate feeds and can be automated thus reducing the labour input compared to the *in situ* degradability technique (Adesogan, 2002). The *in situ* nylon bag and *in vitro* gas production technique are well correlated with animal performance (Orskov, 1989), food intake (Blummel and Orskov, 1993), microbial protein synthesis (Krishnamoorthy *et al*., 1991) and *in vivo* digestibility (Khazaal *et al*., 1993).

2.3.2.4: In Situ Degradation Method

The *in situ* nylon bag technique (Ørskov and McDonald, 1979) is the most widely used in research to determine estimates of rumen DM and protein degradability kinetics, having been adopted in several countries (NRC, 2001; Schwab *et al.*, 2003). However, it is laborious, time consuming and expensive (Cone *et al.*, 2002). It also requires a large number of nylon bags to be ruminally incubated for each feed sample and, in turn, a substantial amount of human work (Olaisen *et al*., 2003). The rate and extent of fermentation of dry matter (DM) in the rumen are very important determinants for the nutrients absorbed by ruminants. Apart from providing a reliable means of predicting the digestibility of feedstuffs in the rumen, the technique further provides information on their degradation kinetics (Ikhimioya *et al*., 2005; Kamalak *et al.*, 2005; Ozkan and Sahin, 2006; Promkot *et al.*, 2007; Jalilvand *et al.*, 2008). The *in situ* method is also routinely used for studying effects of the ruminal environment on digestibility of feedstuffs.

The *in situ* method is the most widely used in research to determine estimates of rumen dry matter and protein degradability (Ørskov and McDonald, 1979) using the non-linear exponential equation:

$P = a+b\ (1-e^{-ct})$

'P' = potential degradation (%) of the nutrient components under investigation after time't';

'a' = the water soluble fraction (%) or intercept at Y-axis representing the portion of DM or CP solubilized at initiation of incubation (time 0);

'b' = the fraction of DM or CP (%) insoluble but potentially degradable in the rumen,

'a+b'= the potential degradability (%) or the upper asymptote;

‘c’ = the rate of degradation (%/hour) of the rumen degradable fraction ‘b’;

‘t’ = time of incubation (hours)

Some adjustments to the original model of Ørskov and McDonald (1979) have since been made. McDonald (1981) introduced a lag time value to the model, to increase the precision when determining the effective degradability. The lag time is defined as the time in which the derivative of the equation of the data sets equals the true potentially degradable fraction at time zero (Mertens, 1993). As such, the new equations would be $P = a + b\ (1 - e^{-c\ (t-L)})$, $t \geq L$ and $ED = a + [bc/(c+k)]\ e^{-kL}$. According to Petit *et al*. (1995), adding the lag time to the model has little effect on the effective degradability. However, the values of fractions a, b and the c are slightly different with the use or non-use of lag time in the model.

Degradation parameters are usually obtained using the polyester or nylon bag technique or *in sacco* technique (Ørskov and McDonald, 1979) or the gas production technique (Menke *et al.*, 1979; Menke and Steingrass, 1988). Degradation is one of the most important quantitative factors determining the nutritional value of feed protein, the supply of ammonia, peptides and branched-chain fatty acids to ruminal microorganisms, and the passage of undegradable proteins to the intestine (Hvelplund and Weisbjerg, 2000). The washout fraction is assumed to be rapidly degradable and that a truly undegradable fraction exists that remains after prolonged incubation in the *in sacco* technique.

Protein in feeds is, to a large extent, degraded in the rumen and its ruminal degradation is often described by the first order mass action model (Hvelplund and Weisbjerg, 2000). The model considers crude protein (CP) of feed to consist of multiple fractions, which differ greatly among themselves in relation to degradation rates, and that the ruminal disappearance of protein is the result of two simultaneous activities: degradation and passage (NRC, 2001). Several methods have been used to divide CP into rumen degradable protein (RDP) and rumen undegradable protein (RUP). These methods include *in vivo* and *in situ* evaluations, and a variety of *in vitro* methods (Schwab *et al*., 2003). In theory, *in vivo* methods are preferred to measure the digestibility of nutrients. However, *in vivo* techniques require large quantities of feed and a large number of repetitions to overcome the variations related to the animal and other factors. Moreover, the concept of animal welfare has contributed to a reduction in the number of *in vivo* experiments. This has led to increased interest in using *in vitro* and *in situ* techniques (Broderick and Cochran, 2000).

The degradability of a protein in forage in the rumen depends on forms of protein reserves (Wallace *et al.*, 1987); where physical and chemical features of forage, which may undergo ruminal fermentation, are located in the cellular walls (Tamminga, 1983). It is affected by season of the year (Ellis *et al*., 1988); degree of lignification (Deinum, 1984) and type of conservation (Vik-Mo, 1989). Dry matter intake (NRC, 2001) and specific diet components, such as concentrate and forage (Seo *et al.,* 2006). These important factors affect the rate of passage and, consequently, the content of rumen degradable protein and rumen degradable protein in the feeds. However, due to the complexity of modeling, some factors that exert an effect on the rate of passage (size, density and rate of particle hydration), are not yet included in the models for *kp* prediction.

Despite the broad use of the *in situ* method to determine the ruminal degradability, there is still a wide variation in the results obtained in different laboratories. The variations come from: pore size of the bag material and fineness of grinding, effect of washing, diet and between animal variations (Kempton, 1980). However, major source of variation is associated with the composition of the basal diet, type of samples and animals, replication, incubation conditions, washing technique and correction for microbial contamination (Kempton, 1980; Broderick and Cochran, 2000).

Other factors are treatment and preparation of samples, sample size, position in the rumen, incubation time: replication, diet of the animal and number of bags incubated (Ørskov *et al.*, 1980). These factors were later categorized as animal characteristics, substrate characteristics, bag characteristics, temporal characteristics, mathematical components and other procedural aspects (Vanzant *et al.*, 1998). Thus, standardizing the technique is very important to allow an adequate evaluation of the feed and a comparison of obtained results. It's also recommended that i*n vivo* and *in situ* trials should be preferably conducted in animals consuming the feeds or the diets of interest, to limit the diet effects and to achieve a rumen fluid "ideal" in terms of microbial population (Vanzant *et al.*, 1998; Kitessa *et al*., 1999).

In the last few years the use of *in situ* technique has been strongly criticized by public opinion for the need of fistulated animals and has raised ethical and moral issues about animal welfare (Stern *et al*., 1997). Among the main problems encountered when using the *in situ* method to evaluate the degradation of protein in forages, the main one is the high proportion of water-soluble material contained in the forages that the technique mistakenly considers degradable.

Additionally, the effect of microbial contamination can be more important in forages due to its high fibre and low protein levels (Calsamiglia *et al.*, 2000). The need for rumen fistulated animals also contributes to increased costs to determine the RDP and RUP using the *in situ* technique (Schwab *et al*., 2003). However, it has the advantage that it uses the rumen environment to measure feed degradation and for this reason it is often the standard against which the *in vitro* methods are frequently compared (Kitessa *et al.*, 1999) and have been adopted in several countries (Schwab *et al*., 2003) as well as by the NRC (2001).

2.4: Characterization of Livestock Systems in Kenya

Several studies have been executed to characterize farming systems in Eastern Africa. Fonteh *et al.* (2005) characterized a peri-urban small-scale dairy farm in the Lake Crescent Region of Uganda as a farm with five or less cows, located at the outskirts of town (between approximately 5 and 10 km away from town) and limited land availability (< 2acres). Sands (1983) made an in-depth study of the contributions of animals in two districts of Western Kenya (mean size 1.03 ha). Using a two dimensional model (household market and household farm) two major subsystems requiring labour and capital were characterized. Odhiambo (1998) used partial analysis to classify farmers in Meru and Machakos district of Kenya into different groups according to proximity to markets, the degree of market orientation and farm size.

Staal *et al.* (1998 and 2001) and Waithaka *et al.* (2002) characterized dairy systems in Kenya by means of cluster analysis where a set of variables considered to reflect the primary measures of variability within that were chosen. Staal *et al.* (1998 and 2001) characterized into four clusters dairy systems in Kiambu district located in Central highlands of Kenya in terms of level of intensification, household resources and access to markets and services. Waithaka *et al.* (2002) characterized into eight clusters dairy systems in Western Kenya region in terms of livestock management of the dairy system, management of the land, cropping system and level of access to input and output markets, and services. Otieno *et al.* (1999) cyclically monitored for six months a herd of 124 cattle from 11 farms in Teso district. Herd characteristics, reproductive performance, feeding management, productivity and herd health were used in characterization. Different classes of animals were identified, 25% were bulls and of the milking cows, 81% were over 6 years old and mostly in their second or third lactation indicating long calving intervals.

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3.0: CHARACTERIZATION OF SMALL-SCALE DAIRY CATTLE PRODUCTION SYSTEMS IN COASTAL LOWLANDS OF KENYA

3.1: Introduction

The Kenya livestock industry contributes to the national economy through generation of both tangible and intangible products and benefits. Livestock serves as main means of livelihood, income generation, employment and food for majority of rural households (Nicholson *et al*., 1998; Udo and Corneliseen, 1998; Thornton *et al*., 2002; GoK, 2004). It also contributes to the sustainability of mixed crop-livestock production systems (Nicholson *et al*., 1998). This is achieved through recycling nutrients, increasing the availability of existing nutrients (with manure) and enabling the storing (carbon sequestration) of nutrients until needed through the storing and composting of manure (Lekasi *et al*., 2001). Estimates show that 53% of the rural poor keep livestock which are often the main means for income generation and about 28% of income of the richest 20% and about 61% of the income of the poorest 20% of rural households comes from livestock in Kenya (Thornton *et al*., 2002). The objectives of this study were to: (i) describe the socio-economic characteristics and (ii) characterize crop-livestock production systems of small-scale dairy cattle farmers in Coastal Lowlands of Kenya.

3.2: Materials and Methods

3.2.1: The Study Area

The study was carried out in the Coastal Lowlands (Kwale and Kilifi counties) of Kenya (Figure 4). The counties were purposefully selected to represent coastal lowlands of Kenya based on increased land-use intensity, high human and livestock population densities.

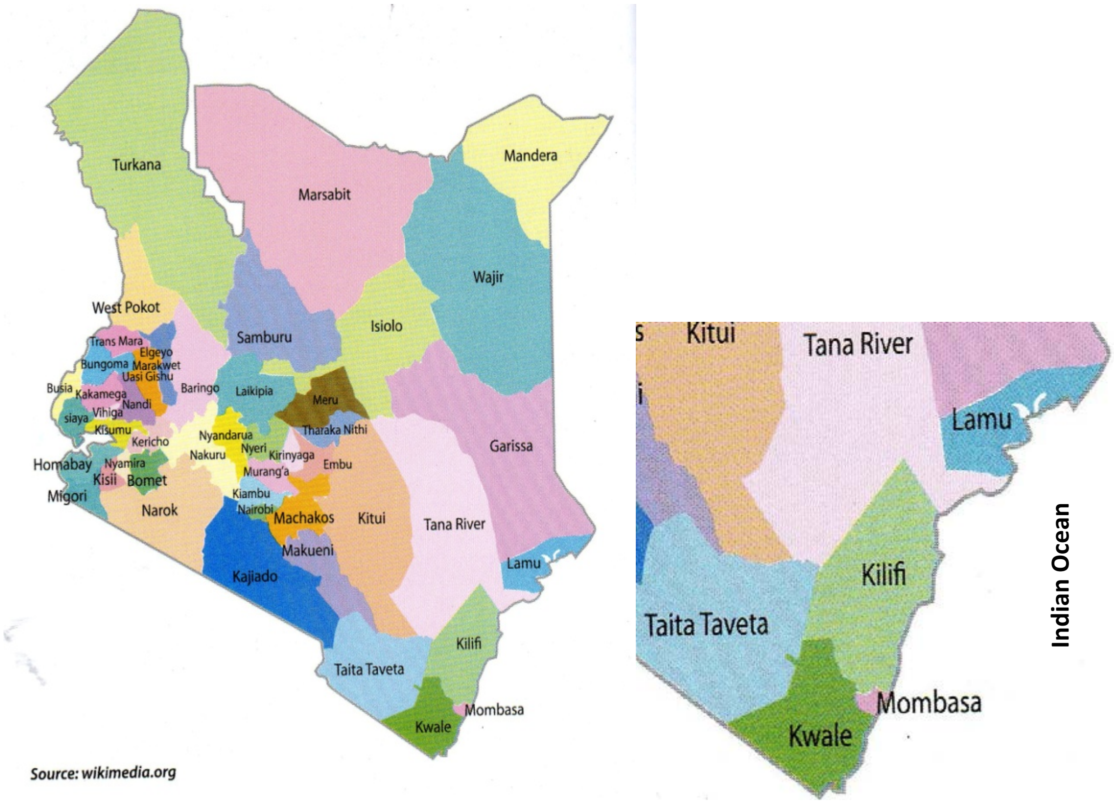

Figure 4: Kenya counties map showing the study site (Right: Map showing Kwale and Kilifi counties)

Kwale County covers an area of 8,270 km^2 with a population of 649,931 persons in 122,047 households (K.N.B.S, 2010a) and stretches along the coast from Mombasa County in the north to the Tanzanian border in the south. Its altitude ranges from sea level to about 420m in the Shimba Hills, through to a gentle westward descent and subsequent ascent to about 849m on Kilibasi hills on the border with the Taita-Taveta County (Jaetzold and Schmidt, 1983). Kilifi County covers an area of 12,609 km^2 with a population of 1,109,735 persons in 199,764 households (K.N.B.S, 2010a). It occupies the area along the coast from Mombasa County at the southern end to the Tana River Delta, and east of Tsavo East National Park. Its altitude ranges from sea level on the Coastal Plain to 705m on the Coastal Range to a maximum of 900m on the Plateau (Jaetzold and Schmidt, 1983).

The two counties are distributed over five agro-ecological zones characterized by different climatic, topographic, soil, and other environmental features that influence the potential of agricultural development. These agro-ecological zones are: Coastal Lowlands 2 (CL2), Coastal Lowlands 3 (CL3), Coastal Lowlands 4 (CL4), Coastal Lowlands 5 (CL5) and Coastal Lowlands 6 (CL6) (Jaetzold and Schmidt, 1983). They also fall into four topographical categories: the Coastal Plain, the Foot Plateau, the Coastal Range, and the Nyika Plateau (Republic of Kenya, 1989a-b). The rainfall is bi-modal, with the long rains between April and June and the short rains from October to December. The highest rainfall was recorded during the month of May at 349 mm and the lowest during the months of January and February at 8 mm each. The annual rainfall pattern is influenced by the Monsoon winds with the main rains coming between late March and early June and decreasing from August. The short rains come in October and November decreasing rapidly to a minimum in months of January and February. The coastal strip and the higher Taita Taveta and Shimba hills receive the highest rainfall of between 1200 - 1600 mm. The lowest rainfall range is 200 - 400 mm which is recorded in the North of Tana River County and the Tsavo National Park which is in Taita Taveta County (Jaetzold and Schmidt, 1983). Mean annual temperature ranges from 24°C to 27°C, with maximum temperature at about 30°C during the months, January to April.

Over the years (2005-2014) the annual mean minimum and maximum temperatures have remained fairly constant and ranged from 20.2 - 20.5°C and 27.3 - 28.1°C respectively (Appendix 2). However, the annual rainfall fluctuated widely within the years. It rose steeply from 880.8 mm in 2005 to 1,532.7 mm in 2006. During the 10 years a highest annual rainfall of 1,783.7 mm was recorded in 2007 with the lowest of 616.4 mm in 2012. These extremities in rainfall variability are likely to be accompanied by more changes in the productivity of rain-fed crops and forage, and more widespread water shortages, changing severity and distribution of important human, livestock and crop diseases (ATPS, 2013).

3.2.2: Sample Size Determination

An important characteristic to qualify to be included in the study was presence of dairy cattle breed(s) on the farm. The number of households surveyed in each county was determined as a proportion of the total number of households in the two counties obtained from the 2009 census figures (K.N.B.S, 2010b). The study employed Fisher *et al.* (1983) formula to determine sample size:

$\mathbf{n = [Z^2 (p*q)]/d^2}$ where:

n: desired sample size if the target population > 10,000,

Z: Normal distribution value at 95% level of confidence = 1.96,

p: proportion of target population estimated to have the characteristic under investigation (assume 50% (0.5) if unknown). The characteristic under investigation was having at least one dairy cattle breed.

q: proportion of target population without the characteristic under investigation (1- p = 50% (0.5), and

d: the allowable error = 0.05.

The number of households sampled in Kilifi County and Kwale County is shown in Table 3.

Table 3: Number of households sampled in Coastal Kenya

County	Number of households	Proportion	Calculated number of households	Number of households sampled	Number of households realized
Kwale	122,047	0.4	146	157	105
Kilifi	199,764	0.6	239	258	310
Total			**385**	**415**	**415**

Source: KNBS (2010a)

The sample size was calculated by substituting for the values: $n = [1.96^2 (0.5*0.5)]/ 0.05^2 = 384.16$, hence 385 households with 146 and 239 households in Kwale and Kilifi counties respectively. However, Peeler and Omore (1997) had observed that a large majority of the grade and grade cross cattle were in Kilifi County due to presence of tsetse flies in Kwale County (Maloo *et al*., 1994). Preliminary field survey before data collection confirmed this. In addition, the data was collected within "Cassava based Napier grass silage for increased milk yield during the dry season in Coastal Kenya" project which had three site areas, one in Kwale and two in Kilifi County with each site having 105 respondents. After extrapolation, the actual number of respondents in Kilifi County and Kwale County was 310 and 105 respectively (Table 3).

3.2.3: Research Design

A cross-sectional survey was conducted on a random sample of 415 cattle producers' followed by a longitudinal survey on a purposive sample of 32 farms from the main cross-sectional sample for 12 months. The cross-sectional survey utilized a pre-tested semi-structured questionnaire (Appendix 7.3) while the longitudinal survey utilized a checklist (Appendix 7.4).

3.3: Data Collection

A cross-sectional survey was carried out in Coastal Lowlands of Kenya (Kilifi and Kwale counties) to collect primary data from March - May 2012. Data was collected from a random sample of 415 small-scale cattle producers through household interviews by trained enumerators for two months using a pre-tested semi-structured questionnaire (Appendix 7.3). Of the 415 sample households, 105 were from Kwale County and 310 from Kilifi County. Both qualitative and quantative data was collected. Observation was used to ascertain on data provided from the pre-tested questionnaire especially on acreages of various roughages and zero-grazing status.

3.3.1: Cross-sectional Survey

The research targeted small-scale dairy farmers as at the time of the study. The pre-tested questionnaire was completed through one time visit interview with the household head or in his/her absence, the most senior member available or the household member responsible for day to day management of the farm. Information collected was based on the respondent's recall. Data on household demography, labour, farm inputs, forage types, area under forage, cattle breeds, cattle numbers, cattle age, cattle estimated live weights, cattle feed consumption and milk production estimates on the day before the interview was collected.

3.4: Data Analyses

3.4.1: Descriptive Analyses

The data from the questionnaires was entered into Microsoft Excel software and checked for entry errors. The data was also checked for specification errors such as multicollinearity, heteroskedascity and autocorrelation (Kennedy, 1985). Data was analyzed using SPSS program

(SPSS, 1989) for descriptive statistics and frequencies. Descriptive statistics were used to describe the current production structures and practices of small-scale dairy cattle farms in terms of feed resources, livestock resources, production technology, products income, geographical locations and human population supported. One-way ANOVA tests were conducted to test the differences based on gender and county. Opportunities and constraints to livestock production were identified and prioritized.

3.4.2: Two-Step Cluster Analyses

Two-Step Cluster method using IBM SPSS Statistics 20 (SPSS, 1989) was used. The SPSS Two-Step Cluster operates by extending the model-based distance measure and handles situations with both continuous and categorical variables (Banfield and Raftery, 1993). It utilizes a two-step clustering approach similar to BIRCH (Zhang *et al*., 1996) and has the capability to automatically find the optimal number of clusters. In the first step, cases are assigned into pre-clusters and these pre-clusters are treated as single cases in the second step. In the second step, the hierarchical algorithm is used to cluster the pre-clusters.

To determine the number of clusters automatically, the first step calculates Bayesian Information Criterion (BIC) for each number of clusters within a specified range and uses it to find the initial estimate for the number of clusters. The second step refines the initial estimate by finding the greatest change in distance between the two closest clusters in each hierarchical clustering stage. This takes sub-clusters resulting from the first step as input and then groups them into the desired number of clusters. In the process of clustering, continuous variables are standardized by default so that they all contribute equally to the distance or similarity between cases.

The variables used in the two-step analysis that might distinguish between the clusters were selected *apriori* (before commencement of the study). The initial delineating variables used were: sex of household head-HHSEX (1 - male; 2 - female), production system - PSYSTEM (1 - zero grazing system [ZGS]; 2 - semi zero-grazing system [SZGS]; 3 - free range grazing system [FRGS]), concentrates feeding - CONCFEED (0 - No; 1 - Yes), land size in acres - LANDSIZE and cattle farming experience in years - FARMEXP. The validity of the cluster solutions was tested by analyzing separate sub-samples according to the counties and the results compared. They were cluster-analyzed separately based on the five variables selected *apriori*. Discriminant analysis was carried to determine which characteristics differed across the identified clusters. This was done using demographic and socio-economic variables not previously considered in the cluster procedure in order to ascertain the profile of each cluster. At this stage, the emphasis was on the characteristics of the clusters as identified.

3.5: Results and Discussions

3.5.1: Households' Characteristics in Coastal Lowlands of Kenya

The characteristics of the households' varied by gender and county in the study area as shown in Table 4. A household head was the member of the household who made decisions on a day to day basis and whose authority was honoured by all members of the household. Female headed households included those where husbands worked and lived elsewhere and the wife was thus the *de facto* head as defined above, widows and unmarried women. In this study, the household head was recognized as the overall farm manager, while with few exceptions where the husband was the household head, the wife managed the farm. Of the sampled households, 62.9% were male-headed and 37.1% were female headed.

Table 4: Households characteristics by gender and county

Characteristics	Household head gender		County		Whole sample		
	Female	Male	Kilifi	Kwale	Overall	S.D	Range
Proportion of households (%)	37.1	62.9	74.7	25.3	-	-	-
Household head age (years) [b]	51.2	51.0	50.0	54.3	51.1	10.8	26 - 86
Dairy cattle farming experience (years)	7.6	7.9	7.9	8.2	7.8	5.6	1 - 30
Number of household members [b]	6.8	7.1	7.3	6.3	7.0	3.3	1 - 18
Male head of household (%)	-	62.9	63.9	60.0	62.9	-	-
Household head works off-farm (%) [a]	11.7	24.5	18.4	23.8	19.8	-	-
Hired casual labourers (%) [b]	34.4	33.7	50.5	28.4	34.0	-	-
Hired long-term labourers (%) [b]	26.0	32.2	56.2	21.0	29.9	-	-

S.D is standard deviation; [a] household head works off-farm was significant at P<0.05 by gender; [b] household head age, number of household members, hired either casual or long-term labourers; hired casual and long-term labourers were significant at P < 0.05 by county.

The mean age of household head was 51.1 years with the range from 26 - 86 years, while the mean dairy cattle farming experience was 7.8 years and ranged from 1 - 30 years (Table 4). The mean age of household head was 50 years in Kilifi County and 54.3 years Kwale County (P < 0.05). The overall mean age of the household head was comparable to the 52.4 years reported by Mwatsuma (2013), but was lower than the 56 years reported by Ramadhan *et al*. (2008) for the same region. The mean size of household was 7 members with a range of 1-18. A household as used in this study was a person or group of persons residing in the same homestead or compound but not necessarily in the same dwelling unit, had the same cooking arrangements, worked on the same piece of land and answerable to the same household head. Nicholson *et al*. (1999) reported that it is often difficult to assess household size in Coast region due to differences in the definition of 'household member' and the tendency for some household members to work away from the farmstead during parts of the year.

There were no marked differences between male- and female-headed households except in whether the household head worked off-farm or not (Table 4). Majority (80.2%) of household heads were full time farmers with only 19.8% working off-farm. Almost twice the number of male household heads (24.5%) worked off-farm compared to females (11.7%) which agrees with Leegwater *et al*. (1991) assertion that women were less likely to work off-farm than men. This importance of off-farm activities results from the low-to-moderate potential of the region for intensification of agriculture, and the need to diversify household activities to reduce risk. In addition to wages and salaries, some household heads operated small rural businesses such as green grocers and retail kiosks. Off-farm employment has become an important source of income for rural households, partly due to the development of the tourism industry in coastal Kenya (Nicholson *et al*., 1999).

About a third of households employed either long-term (29.9%) or casual labour (34%). However, some farms engaged both casual- and long-term farm labour concurrently depending on demand. In Kwale and Kilifi counties, 28.4% and 50.5%; 21.0% and 56.2% employed casual and long-term labourers respectively. A higher proportion of farmers (75.2%) in Kwale County engaged hired labour than in Kilifi County ($P < 0.05$). This could be attributed to fact that, more household heads in Kwale county worked off-farm and not available for farm work. Therefore, hired labourers apart from providing much of the additional labour required, may have positive effects on secondary employment generation. Previous studies suggest that households with dairy cows hire more workers and pay higher total wages than those without (Leegwater *et al*., 1991).

Dairy production is labour intensive due to activities undertaken along the production chain. The activities range from fodder planting, weeding and harvesting, care of the animals to marketing of products which can increase the intensity of household labour use and generate hired employment. This may stimulate the demand for labour, providing benefits to unskilled labourers and distributing the gains from dairy production more broadly and progressively. Labour resources consisted of the household members, hired casual and long-term labour at some point in the production chain as necessary. Labour demand for small-scale mixed farmers is high throughout the year, but probably increases in the dry season when forage is scarce.

The distribution of household head age by gender and county varied as shown in Table 5.

Table 5: Distribution of household head age by gender and county

Distribution of household head age (%)	**Household head gender**		**County**		**Whole sample**
	Female	**Male**	**Kilifi**	**Kwale**	
< 41 years	16.2	16.2	20.3	6.7	16.9
41 – 50 years	33.8	30.7	31.6	32.4	31.8
51 – 60 years	32.5	34.9	32.3	39.0	34.0
> 60 years	17.5	17.2	15.8	21.9	17.3

Majority of household heads (34%) were between 51 – 60 years while 16.9% were less than 41 years old. The results of this study indicated that small-scale dairy farming was mainly in hands of older members of the household.

3.5.2: Household Dynamics

The mean household size, age, proportions and distribution of household members varied as shown in Table 6. The mean household size was 7 members per household (Table 5) with an average of 2.5 members aged less than 18 years, 2.5 members between 18 - 35 years, 1.5 members between 36 - 55 years and 0.5 members above 55 years.

Table 6: Mean household size, age, proportions and distribution of household members

Age (years)	Mean	Standard deviation	Range	Proportions (%)	% households with > 0 members
< 18	2.5	2.1	9	37.9	79.1
18-35	2.5	2.0	11	33.8	84.6
36-55	1.5	1.3	10	21.9	76.4
> 55	0.5	0.7	2	6.4	44.0
Total	**7.0**	**3.3**	**17**		
Distribution of household members					
1-5 members				37.8	
6-11 members				50.8	
> 11 members				11.4	

An average of 37.8% of households had between 1 - 5 members, 50.8 % had 6 - 11 members' while11.4% had more than 11 members. The results showed a high proportion of family sizes of members aged less than 18 years, between 18 - 35 years and 36 - 55 years. This may be explained by the social set up where married sons and their families lived and worked on the same piece of land and remained answerable to their parents. Alternatively, sons worked off-farm but their families worked on the same piece of land as their parents. Consequently, they were answerable to their parents on agricultural issues and in a few cases due to polygamy. Members of households less than 18 years old constituted 37.9% of the population while those over 55 years old were only 6.4%. The less than 18 years old is the most unproductive group as most of them are in school and comparable to 41% attending school in rural areas (KNBS, 2010b).

3.5.3: Educational Profile of Household Heads

The education levels attained by household head differed based on gender and county as shown in Table 7. Overall, majority (61.4%) of household heads had attained primary and secondary levels of education while 14.7% had a post-secondary level. These results reflect the national trend where the large proportion of the popultion has attained primary and secondary education (68%) and post-secondary education (12%) (KNBS, 2010b).

Table 7: Household head education by gender and county

Household head education level (%)	**Household head gender [a]**		**County [b]**		**Overall**
	Female	**Male**	**Kilifi**	**Kwale**	
None	41.6	13.4	27.1	14.3	23.9
Primary	32.5	39.1	38.4	31.4	36.6
Secondary	17.5	29.1	21.6	34.3	24.8
Technical college	8.4	15.7	11.3	18.1	13.0
University	0	2.7	1.6	1.9	1.7

[ab] level of household head education was significant at $P < 0.05$ by gender and county.

More farmers in Kwale County (85.7%) had attained formal education than in Kilifi County (72.9%). However, more farmers in Kilifi County (76%) had attained formal education than in Kwale County (72%) (KNBS, 2010b) compared to study results. The difference could be probably attributed to sample size. The level of education had an effect on off-farm employment and explains why in Kilifi County, a lower proportion of household heads worked off-farm (18.4%). Kwale County had a higher proportion of household heads who worked off-farm (23.8%), perhaps reflecting the fact that more of these had attained secondary and post-secondary education levels thus better economic opportunities off-farm.

A larger proportion of female household heads (41.6 versus 13.4%) had no formal education and had lower proportions attaining higher levels of education than the male counterparts (Table 7). Therefore, male farmers had a better capacity of acquiring dairy technologies and instructions which required some level of education. No female household head had attained university education in the two counties. These results reflect the national trend where females have lower literacy rates and lower levels of education than the male gender (KNBS, 2010b). Education is important for human resource development as it impacts knowledge and skills to individuals necessary for dairy cattle sector development. In fact, educated farmers are more able to manage new technologies or they became aware of productive innovations at earlier stages of growth than their less- educated counterparts (Foster and Rosenzweig, 1996).

3.5.4: Land Resources Management

The mean size of farms varied considerably across the surveyed households by county as shown in Table 8.

Table 8: Land utilization by gender and county

Land (acres)	Household head		County		Whole sample				
	Female	**Male**	**Kilifi**	**Kwale**	**Overall**	**S.D***	**Mini**	**Maxi**	**(%)**
Total land size [a]	5.1	5.3	4.4	7.7	5.3	4.9	0.25	30	100
Napier grass [a]	0.8	0.7	0.6	1.0	0.7	0.8	0	5	13.7
Maize [a]	1.7	1.8	1.5	2.7	1.8	1.5	0	8	34.1
Natural pastures [a]	2.6	2.8	2.3	4.1	2.7	3.6	0	26	52.2
Land distribution classes (%)									
< 6 acres	66.9	68.4	68.4	53.3	-	-	-		68.4
6-11 acres	18.8	22.6	20.3	23.8	-	-	-		20.3
> 11 acres	14.3	14.2	11.3	29.2	-	-	-		11.3

[a] total land size, napier grass, maize and natural pastures were significant at P < 0.05 by county' *S.D is standard deviation.

The overall mean land size was 5.3 acres and ranged from 0.25 - 30 acres. The current acreage was higher than the reported mean agricultural land holding of 3.8 acres for Coastal Lowlands (KNBS, 2010b). Households in Kwale County had larger ($P < 0.05$) average landholdings (7.7 acres) compared to Kilifi County (4.4 acres). This was consistent with the findings of Ramadhan *et al*. (2008) who observed that farmers in Kwale had larger farm sizes (mean 10 acres) than in Kilifi County (mean 8 acres). Earlier studies reported a much higher *per capita* landholding of 27.2acres (11 ha) (Leegwater *et al.*, 1991) and 10.9 acres (4.4 ha) in Kilifi (van der Valk, 1992). However, Mwatsuma (2013) reported smaller land sizes for Kwale at 3.6 acres and larger land sizes for Kilifi at 6.6 acres and attributed this to land tenure system where in the former the farmer owned all the land they occupied and in the latter 14% of the farmers were in family land which had not been sub-divided. The lower landholding sizes in the current study for the two counties indicate an increase in human population density and much more for Kilifi County. Of the respondent households, 68.4% had less than 6 acres, 20.3% had more than 6 - 11 acres and 11.3% had more than 11 acres.

The mean acreage under maize was 1.8 acres with a range of 0 - 8 acres, while natural pastures had a mean of 2.7 acres and a range of 0 - 26 acres (Table 8). Proportionately the amount of land allocated to the different crops in Kilifi and Kwale counties was similar at 13.6, 34.1 and 52.3% and 13.0, 35.1 and 53.2% under napier grass, maize and natural pastures respectively. The area under natural pastures included land under cashew nuts, coconut, mangoes and other trees on the farm. Mureithi *et al*. (1998) observed that farmers in coastal Kenya gave preference to maize when allocating farm resources and the current results reflect this where it more land than napier grass.

The mean land area under napier grass was 0.7 acres with a range of 0-5 acres (Table 8). This was an indication that some farmers with dairy cattle did not grow napier grass on their farms. The proportion of land under napier grass (13.7%) was higher than 8.1% and 7.8% reported by Nicholson *et al*. (1999) for grade cross cattle adopters in Kwale and Kilifi county respectively. However, it was less than 0.4 ha per cow recommended by Stotz (1983) for one dairy cow. It was also lower than NDDP recommendation which advocated and emphasized on zero grazing and the growing of at least one acre of Napier grass *(Pennisetum purpureum*) per cow as the primary forage source (NDDP, 1992a). Nicholson *et al*. (1999) and Ramadhan *et al*. (2008) reported a decline in area under napier grass between 1993 - 1999 and 2004 - 2009 respectively. Competition for space with other crops, drought, technical knowhow and availability of clean planting materials were identified by farmers as major constraints responsible for the decline by Mwatsuma (2013).

3.5.5: Sources of Dairy Cattle

Farmers acquired dairy cattle from various sources and for different reasons as shown in Table 9.

Table 9: Sources and reasons for acquiring grade dairy cattle

Parameters	**County**		**Househouse head**		**Overall**
	Kilifi	**Kwale**	**Male**	**Female**	
Sources of dairy cattle (%) [a]					
Direct purchase	85.8	61.9	73.2	67.5	75.9
Development Project	12.6	27.6	23.4	27.9	20.2
Upgrading local cows	1.0	5.7	1.9	2.6	2.2
Gift	0.6	4.8	1.5	1.9	1.7
Reasons for acquiring grade dairy cattle (%) [a]					
Increase milk for sale	52.3	41.9	48.7	51.3	49.6
Milk for home consumption	34.8	32.4	31.4	39.0	34.2
Body conformation	11.6	21.1	16.5	9.7	14.0
Extension advice	1.3	4.8	3.4	0	2.2

[a] ***Sources of dairy cattle and reasons for acquiring grade dairy cattle significant ($P < 0.05$) by county.***

The two main routes towards acquiring a dairy cow identified were through purchasing an upgraded or grade cow (75.9%) and development projects (20.2%). A few farmers got dairy cows at no cash cost or pre-condition(s) as a gift (1.7%) while 2.2% upgraded their local cows. The proportion of direct purchase was higher than the 50% reported by Nicholson *et al*. (1999) in a study where the adopters acquired a single dairy cow through purchase with cash saved by the household. Improved cows which were mainly donations from development projects probably triggered the need to venture into dairy farming due to their high milk yields (Nicholson *et al*., 1999). Upgrading local cows through artificial insemination or dairy bulls was practiced by 2.2% of the households. As a process, it takes a number of generations before getting the desired results. In addition, it is risky as one is not assured of getting a female calf for use in the next generation and the upgraded animal may die before attaining high grade status. The crossbreeds were mostly obtained through upgrading local cows enabling a farmer to dramatically reduce the entry cost, as the costs of raising the heifer are spread out over time. However, there was a risk of losing the animal during that period. Those who obtained the cows either as a gift from parents or groups (e.g. church groups) or through projects were 21.9%. In this arrangement, the family/group expected something in exchange and/or the project required some conditions to be met.

The development projects in the area were either Plan International (PI) or Heifer International Kenya (HIK) where members of the same cell in a group gave out the first heifer to a fellow cell member. Therefore, relevant developments projects in the study area would increase the propensity of small-scale farmers to go into dairying. Baltenweck (2000) reported that one of the main constraints to the adoption of the grade cattle technology was cost of a grade cow in Kenya highlands. Some previous studies of dairying at the Kenya coast (Leegwater *et al.,* 1991) have suggested that only wealthier households and those with significant non-agricultural income could afford the investment in a dairy cow particularly with high mortality.

The need to produce more milk for sale (49.6%) and home consumption (34.2%) were the main reasons for acquiring improved dairy cows in the study area (Table 9). In Kwale and Kilifi counties, the need for more milk for sale and home consumption was the driving force for acquiring grade dairy cows ranked at 41.9% and 32.4% and 52.3% and 34.8% respectively. Gender of household head did not significantly affect the reason for acquiring grade dairy cattle. However, more of the female headed households tended to rank the two economic reasons of a desire to produce more milk higher but the non-economic reason of physical appearance of the animal lower than their male counterparts. This finding agrees with the adoption and impact study in coastal Kenya in which more milk for sale and home consumption were ranked as first and second important reasons for adopting grade crossbred cattle (Nicholson *et al*., 1999).

Extension played a minor role in influencing acquisition of dairy cow as it contributed 2.2% (Table 9). Extension agents encouraged farmers to acquire either purebred or crossbred animals as a vehicle for increased accumulation of productive capital. Dairying requires acquiring a specific knowledge, especially on feeding strategies and diseases controls (Brumby and Gryseels, 1984). It is a very specific activity compared to indigenous cattle and availability of extension, veterinary and artificial insemination services are expected to foster adoption. Therefore, methods used to deliver technology to farmers may affect adoption levels and increase the expected profitability of the enterprise. Extension services have been identified in the literature as a means to complement formal education and are the main avenues of government influencing adoption of technology by farmers (Baltenweck, 2000). It is thus expected that the availability of these services increase adoption. However, extension visits were not randomly distributed among the farmers population but that the farmers who were more willing to adopt received more extension services visits than others. Extension services to small-scale dairy cattle farms may ultimately have a significant impact on the current milk deficit, if institutional problems in service delivery can be overcome in the Coastal Lowlands.

The proportions of various breeds of cattle in study area are shown in Table 10.

Table 10: Types of cattle breeds kept

Breed	**Breeds proportion (%)**
Friesian	29.9
Cross breeds	25.2
Jersey	21.1
Aryshire	19.2
Brown Swiss	3.0
Guernsey	1.4
Zebu	0.3

Crossbreeds between grade cattle with zebu.

The most common breeds of cattle kept by farmers were Friesian (29.9%) and cross breeds (25.2%). Farmers interviewed reported that crosses were obtained by upgrading of local cows through artificial insemination and grade bulls while improved breeds were mainly donations by development NGOs, particularly Heifer International Kenya. Ramadhan *et al*. (2008) reported a herd structure of cattle breeds kept by farmers as Friesian (23%), Guernsey (17%), Boran (17%) and their crosses with small East African Zebu (43%) for the region. The difference could be attributed to the target population from which the sample was drawn from. The target population was small-scale dairy farmers supported by Heifer International Kenya (HIK) and self financed farmers with dairy cattle breeds as at the time of the study. This herd structure was different from that of exotic-zebu crosses (41.7%), Friesians (34.3%), Aryshire (22.4%) and Jerseys (1.6%) for Western Kenya reported by Wanjala and Njehia (2014).

3.5.6: Livestock Resources

The mean number of various animal species varied by household gender and county is shown in Table 11.

Table 11: Mean livestock numbers and distribution by gender and county

Types of livestock	Household		County		Whole sample				
	Female	Male	Kilifi	Kwale	Overall	S.D*	Mini	Maxi	Proportion (%)
Indigenous poultry	12.3	11.2	12.3	9.6	11.6	12.5	0	84	64.0
Small ruminants [a]	2.7	2.6	2.2	4.0	2.6	4.4	0	30	14.5
Cattle	3.9	3.9	3.6	4.8	3.9	3.3	1	35	21.5

S.D is standard deviation; [a] small ruminants significant ($P<0.05$) by county.

Farmers kept cattle (exotic, exotic local crosses and indigenous), small ruminants (sheep and goats) and indigenous poultry. The dairy cattle herd size ranged from 1 - 35 cattle per farm with a mean of 3.9 heads while the number of small ruminants ranged from 0 - 30 with a mean of 2.6 animals per farm. The mean number of cattle did not vary significantly ($P > 0.05$) between male-headed and female-headed households who had a mean of 3.9. The indigenous poultry mean flock size was 11.6 birds per farm with a range of 0 - 84. It was slightly higher in female-headed households than male-headed households. In this study, only 4 households kept broilers (total=3,000; range =200-1500) and 7 kept layers (total = 3,605; range = 100-1000) and were not used in calculation of the proportions in the total herd size due to low numbers. Of the surveyed households, 77.8% kept indigenous poultry and 41.9% small ruminants. Farmers in Kwale County had a larger average number of cattle and small ruminants while those in Kilifi County had more indigenous poultry. This was in agreement with the most recent census data showing a higher number of cattle in Kwale than Kilifi County (K.N.B.S, 2010b). Farmers in Kwale County had more mean land area under napier grass and natural pastures than those in Kilifi County (Table 8). This was reflected in the higher mean number of cattle per household in the county.

The cattle herd structure in the study area was as shown in Table 12.

Table 12: Cattle herd structure on small-scale farms

Herd composition	**County**		**Whole sample**					
	Kilifi	**Kwale**	**Overall**	**S.D***	**Mini**	**Maxi**	**Herd proportion (%)**	**% of total farms**
Herd size	3.6	4.8	3.9	3.34	1	35	100	100
Lactating cows	1.2	1.2	1.2	1.03	0	8	30.7	80.5
Dry cows [a]	0.5	1.0	0.6	1.01	0	8	16.3	41.9
Bulls (> 3 years) [a]	0.2	0.8	0.4	0.89	0	6	9.6	21.4
Immature bulls (> 3 months-3 years)	0.5	0.3	0.4	0.72	0	5	11.1	34.0
Heifers (> 3 months - calving)	0.8	1.0	0.8	1.48	0	20	21.4	50.4
Male calves (< 3 months)	0.2	0.2	0.2	0.47	0	3	4.9	16.1
Female calves (< 3 months)	0.2	0.3	0.2	0.53	0	4	6.0	19.5
Cattle class distribution (%)								
1 – 3 cattle	63.9	52.4	-	-	-		61.0	-
4 – 6 cattle	26.1	24.8	-	-	-		26.3	-
7 – 10 cattle	6.1	11.4	-	-	-		7.5	-
> 10 cattle	3.2	11.4	-	-	-		5.3	-

S.D is standard deviation; [a] dry cows and bulls (> 3 years) significant (P < 0.0.5) by county.

There were no significant differences ($P > 0.05$) in herd structure by gender of household head and hence not presented. The herd size ranged from 1 - 35 animals with a mean of 3.9, while a proportion of 30.7% and 16.3% were lactating and dry cows kept by 80.5 and 41.9 of the total farms respectively. Mature bulls constituted 9.6% of the cattle herd and kept by 21.4% of the farms. Farmers indicated crossbreeding with household's local cows and offering breeding services to other dairy farmers as the most important reason for rearing a bull to maturity.

Peeler and Omore (1997) and Nicholson *et al.* (1999) reported that sample households in Kwale County owned a higher number of grade-cross cattle on average than households sampled from Kilifi county. Leegwater *et al*. (1991) reported a mean of 3.9 cows per household in Kilifi County which was similar to the findings in this study. Kwale County had higher land acreage, area under napier grass, natural pastures and maize, which may explain the larger cattle herd size compared to Kilifi County. The cattle herd sizes were generally small with 61% of households having 1-3 and 26.3% at 4-6 head of cattle.

Lactating cows had a mean size of 1.2 cows per farm with a range of 0 - 3 animals while heifers (> 3 months and not calved) constituted 21.4% of the herd and available in 50.4% of the farms (Table 12). The results suggest that there is a major shortage of replacement heifers on 49.6% of the small-scale farms in coastal lowlands. However, this figure is lower than 63% small-scale farms in Western Kenya reported by Wanjala and Njehia (2014) indicating that the situation is not as severe as in other parts of the country. This together with the low proportion of lactating cows may be an indication as to why the coastal region is milk deficient.

Inadequate supply of replacement stock on small-scale farms has been a key concern for the dairy industry as these farms own 80% of total dairy herd population and produce more than 70% of marketed milk in Kenya (Bebe *et al*., 2003; Muriuki, 2011). The situation is exacerbated by collapse or sub-division for human settlement of state farms and large scale private farms that used to produce replacement stocks for small-scale farms often at subsidized prices (Conely, 1998). In the coastal region, although a few large and successful large farms exist, most of milk is produced in small-scale farms. As such, for small-scale farmers in the region to access breeding stock easily in order to maintain and improve their dairy herd populations, produce more milk for sale and home consumption, various strategies such as use of artificial insemination and encouraging the rearing of improved dairy heifers as business by farmers and individual entrepreneurs should be considered.

3.5.7: Feed Resources

The availability of feed resources varied from season to season as shown in Table 13.

Table 13: Incidences of feed shortages during various seasons by gender and county

Seasons of year	Household head		County		
	Female	Male	Kilifi	Kwale	Overall
Season I[1] (%)	49.4	47.5	48.1	48.6	48.2
Season II[2] (%)	11.7	9.2	13.2	1.0	10.1
Season III[3] (%)	89.6	87.4	85.5	96.2	88.2
Season IV[4] (%)	11.7	12.3	14.5	4.8	12.0

[1]Season I: July – September (dry); [2]Season II: October – December (wet); [3]Season III: January - March (dry) and [4]Season IV: April – June (wet).

There were no significant differences in feed shortage either by gender or county ($P > 0.05$). The expected seasonal feed availability followed the rainfall pattern of the area. Feed shortage was critical during the long dry period of January to March (season III) with 88.2% of households experiencing shortages. This feed shortage was less pronounced in season I (July to September) where 48.2% of households reported incidences of feed scarcity. In seasons II (short rains season) and IV (long rains seasons) feed shortages were less pronounced.

Fewer households (10.1%) experienced feed shortage during season II (short rains) than the 12.1% in season IV (long rains). This was an indication that rainfall was more reliable for plant growth during short rains than in long rains. Mureithi *et al*. (2008) confirmed that forage is plentiful and even farmers conserved excess as silage during the short rains. The effects of expected carry-over high biomass production from wet season II in to the dry season III, the effects of long dry season and high animal numbers exacerbated the feed shortages. A strategy to mitigate against the seasonal shortages of feed is conservation during the period of plenty.

In the study area, the proportion of households that had ever conserved forages either in the form of hay or silage varied as presented in Table 14.

Table 14: Feed conservation strategies by gender and county

Parameters (%)	Household head		County		
	Male	Female	Kilifi	Kwale	Overall
Trained on conservation	21.8	15.6	14.8	33.3	19.5
Proportion ever conserved *	14.2	11.0	14.2	9.5	13.0
Proportion conserved hay *	4.2	5.8	5.8	1.9	4.8
Proportion conserved silage *	0.8	0.6	0.6	1.0	0.7

* ***Significant ($P < 0.05$) by county*.**

There were no significant differences in conservation measures by gender although significant differences ($P < 0.05$) existed by county. The results showed low adoption of forage conservation technologies as 13% of 19.5% households trained had ever conserved forage either in form hay or silage. Hay conservation was by 4.8% compared to silage by 0.7% of respondents. Silage making was constrained by inadequate knowledge and fodder for ensiling and hay making by inadequate technical knowhow by the farmers. In Kilifi County, more farmers (14.2%) compared to 9.5% in Kwale County reported to have ever conserved despite having less farmers trained on conservation. This could be attributed to difference in land sizes where farmers in Kilifi had smaller land sizes (4.4 acres) compared to 7.7 acres in Kwale County (Table 8) hence a need to conserve.

Of the two common methods of forage conservation, silage making is technically the most challenging (Mannetje, 2000) which may explain the lower adoption of the technology. The main challenges to silage making reported during the study were inadequate fodder for ensiling and technical knowledge. This was mainly contributed to by the fact that the acreage of napier grass was not adequate for feeding the cows and ensiling. In addition, farmers only knew of napier as the only fodder they could consider for silage making. The technical knowhow of the extension officers' agrevated the situation as only 31% were competent on more than one silage making technique (Mwatsuma, 2013), thus limiting choices in terms of the silage making technique to adopt by farmers. Lack of technical knowhow by extension agents was also identified the reason hampering silage making techniques in Thailand by Nakamanee (1999). Despite farmers in the study area having adopted improved fodder production practices (Mambo *et al.*, 2004) more emphasis in conservation methods is recommended. There was plenty of forage in months of October – December and April – June as demonstrated by the fact that only 10.1% and 12% of households (Table 13) reported incidences of fodder shortges respectively.

Short term strategies employed by farmers to cope with feed shortages are shown in Table 15.

Table 15: Short term strategies to cope with feed shortages

Strategy	1st choice feeding strategy	2nd choice feeding strategy
Feed less to animals	31.6	8.8
Feed tree leaves	30.2	33.2
Reduce herd size	18.2	12.3
Purchase more fodder	16.3	38.8
Rent grazing pastures	3.7	7.0

The strategies ranged from feeding less to animals to renting grazing pastures. During the dry seasons, the forages were inadequate and farmers and labourers had to walk for long distances in search of forages whether for grazing or stall feeding. As a result, 31.6% of farmers opted for feeding less to animals as the most suitable coping strategy. However, feeding less forage amounts to animals led to decreased milk production and hence reduced income. In the past, neighbours used to allow free harvesting or grazing without payment, but 3.7% paid for grazing pastures either in cash or in kind as milk or manure. Forage was purchased from neighbours who did not keep cattle as indicated by 16% of respondents.

Long term strategies employed by farmers to cope with feed shortages are shown in Table 16.

Table 16: Long term strategies to increase milk production

Long term strategies (%)	County		Household head		
	Kilifi	Kwale	Male	Female	Overall
Produce more feed on-farm	55.2	41.0	39.8	52.6	44.6
Purchase more feed off-farm	0	19.7	15.3	13.6	14.7
No strategy employed	44.8	39.3	44.9	33.8	40.7

The long term feeding strategies suggested by respondents to increase milk production were more on-farm feed production (44.6%) and purchase of more feed off-farm (14.7%). As human population size increases, land availability will decrease and intensification of land use as well as greater adoption of high yielding fodder crops including napier grass for production of more feed on-farm will probably be the only viable option to sustain and improve dairy production. Labour requirements for dairy cattle related activities would then increase. In allocating labour for the various farm activities priority was given to food crops production and this was high during the planting and weeding periods of the wet season. At such times management of napier grass (weeding and return of slurry) was not done as recommended. As a result, the productivity of napier grass was low and some stools died during the dry seasons further reducing fodder production. Demand for labour on mixed farms was high throughout the year, but increased in the dry period when forage was scarce as farmers had to walk for longer distances in search of forages.

The utilization of various concentrates, cereal milling by-products and minerals salts in the study area was as shown in Table 17.

Table 17: Use of concentrates, cereal milling by-products and mineral salts

Parameters	Description	Number of farms	Percentage
Commercial concentrate	Dairy meal	89	21.4
Cereal milling by-products	Maize germ	139	33.5
	Maize bran	102	24.6
	Wheat bran	14	3.4
	Local maize bran	29	7.0
Mineral salts	Mineral salts	137	33.0
Overall utilization	**All types**	**286**	**68.9**

Dairy meal was the only commercial concentrate fed to cows in 21.4% of farms. The small number of farmers using commercial concentrates is attributed to the fact that only a few could afford to buy sufficient quantities for feeding their dairy cows though available on the local market. Maize germ (33.5%), maize bran (24.6%) and wheat bran (3.4%) were common cereal milling by-products utilized and available throughout the year but their use was also limited by cost. The utilization of maize germ and maize bran surpassed that of dairy meal and farmers attributed this to their lower cost. Local maize bran from posho mills was used by 7% of the farmers due to low availability. Majority of farms (68.9%) utilized either dairy meal, cereal milling by-products or mineral salts either in combination or singly. This indicated that 31.1% of farms did not use any supplement.

3.5.8: Group Membership

The membership of household heads to farmer's group, women/men group or cooperative society and the duration of membership are shown in Table 18.

Table 18: Household head membership to various groups by county and gender

Characteristics	**Household head**		**County**		**Whole sample**			
	Female	**Male**	**Kilifi**	**Kwale**	**Overall**	**S.D**	**Mini**	**Maxi**
Membership duration (years) [a]	6.8	10.2	8.4	8.5	7.5	4.89	1	25
Member of a group (%) [a]	61.7	41.0	40.0	74.3	48.7	-	-	-
Type of group (%) [b]								
Farmers group	51.6	56.1	39.5	76.9	54.0	-	-	-
Women / men group	37.9	34.6	46.8	19.2	36.1	-	-	-
Cooperative society	10.5	9.3	13.7	3.8	9.9	-	-	-

[a] Group membership duration (years) significant (P < 0.05) by county; [b] being a member of a group significant (P < 0.05) by gender and county; type of group significant (P < 0.05) by county.

Overall, the mean duration of being a group member was 7.5 years and approximately half (48.7%) of household heads belonged to an organized group. Of the 48.7% who belonged to a group, 54% belonged to various farmers groups and 9.9% to cooperative societies. However, more females (61.7%) compared to males (41%) were members of groups. Women unlike men belonged to more than one group. In some instances, the household head was not a member of a group but the spouse was. Kwale County had more household heads being members of groups at 74.3% compared to Kilifi County at 40%. This could be associated with source of dairy cattle in the two counties where in Kwale County 27.6% acquired from development project compared to 12.6% in Kilifi County. Membership could be influenced by what the group does and related benefits. Development projects worked with groups and the incentive to get a dairy cow albeit with pre-conditions may have acted as an incentive. Differences in duration of membership and types of groups were noted among the counties with Kilifi County having higher values for women/men group and cooperative society. In Kwale County more household heads (76.9%) were members of farmers group compared to Kilifi County (39.5%).

3.5.9: Farmers Access to Credit Facilities

Access to and reasons for not accessing credit by the farmers are shown in Table 19.

Table 19: Household head's access to credit and reasons for not sourcing for credit

Access to credit	**County**		**Household head**		**Overall %**
	Kilifi	**Kwale**	**Male**	**Female**	
Ever accessed credit for dairy farming (%)	12.9	14.3	11.1	16.9	13.3
Reasons for not accessing credit (%) [a]					
Fear of inability to service	17.8	13.3	12.5	24.2	16.7
No need for credit	65.9	67.8	68.1	63.2	66.4
No collateral	15.6	6.7	15.1	10.2	13.3
Inadequate information	0.7	12.2	4.3	2.3	3.6

[a] ***Reasons for not accessing credit significant ($P<.05$) by gender and county.***

Access to credit for dairy cattle development was a major obstacle, as only 13.3% of households had accessed credit. Evidence shows that access to credit by small-scale farmers is limited in

Kenya and may constitute an impediment to the uptake of dairy cattle technology even in the well-suited zones (Baltenweck, 2000). Majority of respondents (86.7%) did not seek credit for improvement of their dairy cattle farming enterprise due to various reasons. The reasons advanced for failure to access credit ranged from no need for credit (66.4%) to inadequate information on credit facilities (3.6%). Fear of inability to pay the loans could be associated with low production potential of the dairy cows whose milk production might not be able to service the loans. In the study, 3.6% of respondents cited inadequate information on loans availability, source and conditions as the reasons why they have never taken a loan. This indicated that information on loans was readily available. Mureithi *et al* (1998) reported that inadequate capital which was compounded by fear for acquiring credit by the community and seasonal availability of natural forage and profitability of the enterprise as some of the factors which affected adoption of dairy technologies.

A slightly higher proportion of female household heads (16.9%) had sought credit to invest in dairy cattle farming compared to males (11.1%) (Table 19). Lack of collateral was cited as a reason for not seeking credit to invest in dairy cattle farming by 15.1% and 10.2% of male and female household heads respectively. Access to credit for rural women remains a great challenge as most credit facilities demand title deeds and other productive assets as collateral which they do not have access to (NALEP, 2009). Women were responding to this challenge by producing new options to access credits in form of social based assets in form of merry-go-round groups. In the study area, more female (38.3%) than male (26.8%) household heads were members of organized groups (Table 18) and therefore had more access to group loans resulting in high uptake. However, these groups can only advance minimal loans which are often indequate to manage any meaningful sustainable dairy enterprise venture. In addition, group loans were likely not to require collateral and hence high uptake by members. Twice the number of females (24.2%) compared to males (12.5%) reported that they were afraid of the capacity to pay the loan as the reason for not seeking credit. This was justified for the current milk production levels could not repay a loan.

3.5.10: Objectives of Cattle Farming and Sources of Income

The household ranking of objectives of keeping dairy cattle by county are shown in Table 20.

Table 20: Household ranking of objectives of dairying by county

Objectives of dairying (%)	Kilifi county			Kwale county			Overall ranking		
	1	2	3	1	2	3	1	2	3
Source of income	64.0	34.7	1.3	70.6	26.5	2.9	65.7	32.6	1.7
Home consumption	36.9	61.8	1.3	30.0	69.0	1.0	35.2	63.6	1.2
Manure	2.7	6.8	90.5	2.1	10.6	87.2	2.6	7.7	89.7
Social status	0	3.3	96.7	0	16.7	83.3	0	5.6	94.6

There were no differences ($P > 0.05$) between the two counties in objectives of keeping dairy cattle. In the study area, 65.7% of respondents ranked source of income as the main reason they ventured into dairying. This could be due to cash receipts from daily milk and dairy product sales being distributed more evenly throughout the year compared to income from crop sales. A further 35.2% and 2.6% ranked production of milk for home consumption and manure as their most important objective. However, dairy cattle production is ranked second to vegetables as an enterprise with potential for commercialization (Mwamachi *et al*., 2005). Majority of respondents (89.7%) ranked manure as the third most important reason. This implies that more intensive dairying can also have positive impacts on soil fertility in mixed cropping systems

(Delve *et al.,* 2001). This strong demand for milk should be taken as an indicator of the potential of dairy development in the region. In Kilifi County, 64% of respondents reported income generation as the main objective of keeping dairy cattle compared to 70.6% from Kwale County. This could be attributed to more market opportunities and degree of intensification in Kwale County where majority of farmers practiced zero-grazing system of production (Table 22) despite having large land sizes (Table 8).

The main sources of income in the study area by county and gender are shown in Table 21.

Table 21: Sources of income by county and gender

Source of income (%) [a]	**County**		**Household head**		**Overall**
	Kilifi	**Kwale**	**Male**	**Female**	
Milk sales	62.6	45.7	52.5	55.8	53.7
Wages/salaries	16.1	27.6	25.3	20.8	23.6
Income from cash crops	9.7	15.2	12.3	9.1	11.1
Income from food crops	10.3	15.2	8.4	14.3	10.6
Income from poultry	1.3	-	1.5	0	1.0

[a] ***Respondents sources of income significant ($P < 0.05$) by county.***

Household heads engaged in various on-farm and non-farm activities for generating income. The main source of income for the dairy farmers (53.7%) was income from sales of milk. This was in agreement with Muraguri *et al*. (2000) findings that in coastal small-scale dairy production systems, over 80% of the revenue was derived from the sale of milk. Market-oriented dairy production may fill this need for some small-scale producers, particularly in light of expected rapid growth in milk consumption in the developing world over the next two decades (Delgado *et al*., 1999). The second most important was wages accruing from off-farm engagements contributing 23.6% of household income. Dairying was ranked third based on income earned from the sale of milk and progeny (Mureithi *et al*., 1998). In same study, maize and coconut trees were among the first three profitable enterprises since 1960's to 1990's. In this study, income from food crops was ranked fourth in importance. Therefore, dairy cattle production which offer higher returns to land and labour, offer the expectation of future growth, and is suitable for adoption are needed by the resource-poor small-scale farmers who continue to dominate coastal region dairy cattle production.

In Kwale county, 27.6% of households acquired income from off-farm wages and salaries compared to 16.1% from Kilifi county which may be related to the generally higher education levels especially beyond primary level (Table 7) and thus better employment opportunities compared to those in Kilifi county. More male-headed households cited income generation as the major reason for engaging in dairying while for the female headed households, source of milk for home consumption was more important. These gender based differences probably reflect the fact that as main bread winners males will be more into income generation while women tend to be more concerned about adequate nutrition of their families.

Increased population density has lead to intensification of small-scale agriculture in coastal lowlands. This implies that dairy farming has the potential of becoming an important enterprise option for significant number of resource-poor families and should not be treated as one of these options to be engaged in from time to time as the opportunity arises. In addition, the profitability of different enterprises is changing with time. Nicholson *et al*. (1999) reported that households have various non-agricultural options for generating income that may serve the same purposes, and dairying therefore represents only one of many alternatives. As a result, some households will own dairy cows when their circumstances allow it, but these same households may temporarily cease dairying due to the death of an animal or the perception that other opportunities are more remunerative and/or less risky.

3. 5.11: Production Systems

Farmers practiced a variety of dairy cattle production systems as well as feeding management practices as shown in Table 22. Overall, 47.7% of small-scale farms practiced semi zero-grazing system which combined stall feeding with tethering and free grazing. Zero-grazing system was practiced by 22.7% farms where dairy cattle were confined in sheds. Field observations indicated that about 80% of the zero-grazing units were in poor condition. In some cases, cattle were tethered in the zero-grazing units.

Table 22: Dairy cattle production systems and feeding practices by county and gender

Characteristics	County		Household head		Overall proportion (%)
	Kilifi	Kwale	Male	Female	
System of production (%) [ab]					
Semi zero-grazing system	49.9	42.9	43.3	55.2	47.7
Zero-grazing system	14.8	45.7	22.2	23.4	22.7
Free range grazing system	23.2	3.8	20.7	14.3	18.3
Tethering system	12.6	7.6	13.8	7.1	11.3
Feeding management practices (%)					
Cut and Carry [ab]	66.8	96.2	68.6	83.8	74.2
Graze animals [b]	83.9	50.5	76.2	74.0	75.4
Graze under tree pastures [b]	77.1	46.7	69.0	70.1	69.4
Graze crop land [b]	61.0	37.1	51.7	60.4	57.9
Graze road side pastures [b]	5.2	24.8	10.3	9.7	10.1

[a] Systems of production and cut and carry feeding system significant ($P < 0.05$) by gender; [b] systems of production and all feeding management practices significant ($P < 0.05$) by county.

Various types of feeds such as napier grass, natural pastures and crop residues, fodder purchased from neighbours, forages collected from common public properties (road and forest reserves, schools) and purchased concentrates were brought in. However, it required more labour than the common semi-extensive cattle production practice of semi zero-grazing. Households in the coastal area often use tethering and grazing methods of feeding their dairy cattle (Swallow, 1998). In Kwale County, majority of households (45.7%) practiced zero-grazing system compared to 14.8% in Kilifi County despite having bigger land size of 7.7 acres as opposed to 4.4 acres in Kilifi (Table 8). This may be attributed to the presence of tsetse flies in the county, the vectors for Bovine trypanosomosis (Maloo *et al*., 1994).

Farmers practiced a combination of various feeding management strategies depending on the system of production where 75.4% of households grazed their animals while 74.2% practiced ‘cut and carry’ system (Table 22). Of 75.4% of households, 69.4, 54.9 and 10.1% grazed their animals in pastures under tree crops, cropped land after harvest and road side pastures respectively. Open-grazing of dairy cattle on freshly harvested crop fields where they scavenged on crop residues and weeds was observed as a common practice. In this study, the tree crops included cashew nuts, coconut and mango trees and pastures under these tree crops were grazed and at times ‘cut and carried’ for stall feeding purposes. Pastures under tree crops were an important source of feed and occupied 52.2% of land in the study area.

3.5.12: Dairy Cattle Performance

The mean milk yield/cow/day was 5.7 litres and ranged from 1-17 litres as shown in Table 23. There were no differences ($P > 0.05$) in milk production, farm level milk price and milk income by gender. However, there was a significant difference ($P < 0.05$) between farm level milk prices by county where Kwale had higher than Kilifi. This led to higher income per farm in Kwale

County had than Kilifi County. The high farm-level prices can be taken as an indicator of the potential for dairy development in the region. Breed differences, different animal husbandry management skills and systems, as well as varying physiological stages of lactation did not allow for a between-group comparison of milk production.

Table 23: Milk production of cow (litres/day) and farm level prices by gender and county

Parameters	Household head		County		Whole sample			
	Female	**Male**	**Kilifi**	**Kwale**	**Overall**	**S.D**	**Mini**	**Maxi**
Milk (litres/day/cow)	5.4	5.9	5.8	5.4	5.7	3.1	1	17
Milk price (Ksh/litre) [a]	46.4	44.9	43.8	51.0	45.4	8.8	30	60
Milk income (Ksh/day /farm)	351.8	397.1	363.4	437.1	380.6	343.7	30	3,600
Milk production range (% of farms)								
< 5 litres	46.7	42.5	42.6	48.7	44.0			
5 - 11 litres	50.0	50.9	51.2	48.7	50.6			
> 11 litres	3.3	6.6	6.3	2.6	5.4			

S.D - standard deviation, Ksh-Kenya shillings; a milk price significant (P < 0.05) by county.

Kwale County farmers had higher landholdings, area under napier grass, natural pastures and maize (Table 8) and majority practiced zero-grazing than Kilifi County (Table 22). As such Kwale County would have been expected to record higher milk yields/cow/day than those in Kilifi County. In addition, Kwale County household heads had more access to off-farm employment opportunities (23.8%) compared to Kilifi County (18.4%) (Table 4) and hence less dependence on dairy farming as their source of income (Table 21).

Ramadhan *et al*. (2008) and Mwatsuma (2013) reported that milk production is generally low at 1.0 - 6.4 kg/cow/day for cattle at the coastal Kenya. Majority of farms (50.6%) produced 5 - 11 litres/day/cow, 5.4% more than 11 litres/day/cow and 44% less than 5 litres/day/cow (Table 23). The low average milk yields could be attributed to poor quality of feed and inadequate year-round feed supply, protein and energy intake (Muinga *et al*., 1999; Staal *et al.*, 1998; Msanga *et al.*, 2000; Chamberlain and Wilkinson, 2002), as farmers had little cash to purchase supplementary concentrate feeds (Valk, 1990; Nicholson *et al*., 1999). Farm income from milk sales ranged from Kes. 30 - 3,600 with a mean of 380.6 Kes/day. This income from milk shows there were benefits from efforts to promote ownership of dairy cattle and improve management practices by small-scale households in the region. Impact on household welfare may also occur through increased milk consumption despite increases in milk sales.

3.5.13: Breeding Methods and Bull Calves Management

The breeding methods used in the study area are shown in Table 24.

Table 24: Breeding methods used in the study area

Parameters	Proportion of households (%)
Castrated male calves	81.0
Use natural bull service	78.2
Use artificial insemination (A.I)	14.5
Used natural bull service for repeats	7.3

In the study area, 81% of the households did not castrate their male calves and used them later on for natural service. Majority of households (78.2%) used natural service to breed their cows either with own or neghbours bull. The high usage of natural bull service was attributed to ease of access and its associated low costs ranging from 300 - 500 Ksh/ service compared to 800 - 3,000 Ksh/service for A.I. The main setback of use of natural service was that the bulls were not proven thus retarding genetic progress, increased chances of inbreeding and spread of reproductive diseases. Previous study by Nicholson *et al*. (1999) indicated that saving money previously used for artificial insemination was a strong motivation for acquiring a grade cattle bull by small-scale dairy cattle farmers in coastal lowlands.

Artificial insemination (A.I) has been used by farmers to control breeding diseases and improve production. There were widespread cases of repeat inseminations at a cost and in the event of a repeat, 7.3% of farmers' preferred natural method (Table 24). Farmers attributed repeats to unethical practices, poorly trained personnel as well as poor accessibility during the wet season which further aggravated the A.I. services. The other problem contributing to low usage of AI in the area was lack of variety of semen distributed by Kenya Animal Genetic Resources Institute (KAGRI) and hence limiting the choices available to farmers. Other challenges included inadequate knowledge of farmers on heat detection and A.I. record keeping. However, A.I. was privatized in 1991 due to structural adjustment programmes which represented a shift in policy encouraging private A.I. providers (Owango *et al*., 1998). Therefore, effective and sustainable solutions for A.I. challenges require training of farmers on proper heat detection in the region.

3.5.14: Animal Health Problems and Management Practices

The incidences of various animal health problems varied by county and gender of household head as presented in Table 25.

Table 25: Common animal health problems by county and gender

Common animal health problems (%)	**County**		**Household head gender**		**Overall**
	Kilifi	**Kwale**	**Male**	**Female**	
East Coast Fever (ECF)	56.8	31.4	55.2	42.2	50.4
Worm infestation	31.6	17.1	25.3	32.5	28.0
Bovine trypanosomosis	3.2	41.0	11.9	14.3	12.6
Pneumonia	5.2	3.8	4.2	5.8	4.8
Mastitis	1.3	3.8	4.2	1.9	2.4

The main reported health problems in the two counties were tick-borne diseases (mostly East Coast Fever (ECF)) and worm infestations. The health problems could be attributed to collapsed government services and failure of the private sector to fill the gap (Salami *et al*., 2010). Livestock diseases can cause direct losses (deaths, stunting, reduced fertility, and changes in herd structure) and indirect losses (additional costs for drugs and vaccines, added labor costs and profit losses due to denied access to better markets and use of suboptimal production technology) in revenue (Rushton, 2009). The animal health problems lead to increased production costs, decreased production, lowered product quality and raised safety issues and consequently translated into reduced opportunities for the dairy products in the domestic and export markets.

Bovine trypanosomosis transmitted by the tsetse fly was the most important cattle health problem in Kwale County (41%) while ECF was most important in Kilifi County (56.8%). This prevalence rate was higher than 25% (Ohaga *et al*., 2007) and 33.9% (Mbahin, *et al*., 2013) in the Kwale County. However, earlier reports also indicated that Bovine trypanosomosis was only important to few farmers (11.3%) in Kwale County (Machila *et al*., 2003). In Kilifi County, 96.8% of respondents reported no incidence of Trypanosomosis compared to 59% in Kwale County. In Kwale County, most of the cattle in the study farms were grazed and housed close to Shimba Hills National Reserve where they came into contact with tsetse flies. The higher parasitological prevalence of bovine trypanosomosis observed in the County could be attributed to the higher trypanosome challenge around the National park which was subjected to annual re-invasion (Machila *et al*., 2003).

The higher incidences of tick-borne ECF in Kilifi can be explained by the fact that only 14.8% of households compared to 45.7% in Kwale County zero-grazed their cattle thus exposing them to ticks during grazing. The same argument can be used to explain the higher incidences of worm infestations in Kilifi at 31.6% compared to 17.1% for Kwale County. ECF losses in small-scale dairy cattle can be substantially reduced by immunisation through infection and treatment (Maloo *et al*, 1992a; Mutugi *et al*., 1991). As a pre-condition for sustainable development of small-scale dairy systems, animal disease control measures should be identified in order to reduce loss of animals.

The frequency of tick and intestinal worm control during the 12 months prior to the study varied as shown in Table 26.

Table 26: Frequency of tick and intestinal worm control by county

Frequency	**Kilifi county**		**Kwale county**		**Overall**	
	Ticks	**Worms**	**Ticks**	**Worms**	**Ticks**	**Worms**
Twice a month	11.9	0	0	5.7	20.5	0
Once a month	34.8	29.0	32.4	7.6	34.2	23.6
Every 2 months	32.9	0	21.0	0	29.9	0
Every 3 months	11.9	45.2	45.2	82.9	8.9	54.7
Twice a year	0	3.2	0	0	0	3.9
None	8.4	22.6	1.0	3.8	0	0

- ***No incidence reported.***

During this period, 89.1% of the households reported having sprayed their cattle using knapsack sprayer or hand washed the animals to control ticks. Contrary to the recommended frequency of spraying /dipping and hand washing at least weekly for tick control in the region, 64.1% of respondents reported a tick control frequency of once in 1 or 2 months and 20.5% of twice a month. In addition, 78.3% dewormed their cattle either monthly or at 3 month intervals with

17.8% not deworming. The main reason given for low frequency of spraying acaricides and deworming was the cost of drugs and lack of appropriate equipments.

Farmers used various strategies to the control Trypanosomosis as shown in Table 27.

Table 27: Trypanosomosis control strategies by county and gender

Trypanosomiasis control (%) [a]	**Household head**		**County**		**Overall**
	Female	**Male**	**Kilifi**	**Kwale**	
Use mosquito nets	16.2	11.9	0.3	52.4	13.5
Use trypanocides	18.9	16.9	14.1	27.6	17.6
No control method	64.9	71.3	85.5	20.0	68.9

[a] ***trypanosomiasis control measures significant (P <. 0.05) by county.***

Several approaches to control trypanosomosis and its biological vector, the tsetse fly, were available in the area. During the study, it was observed that small-scale farmers used synthetic pyrethroid pour-on (SPPs), sprays, dips and zero-grazing units enclosed in fly proof nets (referred to as netted units) for the control of trypanosomosis. The control methods targeted either the vector (tsetse fly) that transmits the parasite (trypanosomosis) that causes the disease or use of drugs to cure and/or protect the animal. Others involve selection or breeding of animals that are resistant to trypanosomosis disease; selective clearing of bushes to destroy hiding and breeding places of tsetse flies; use of baited traps or treated targets and biological techniques such as Sterile Insect Technique (SIT) or predators (Mbahin, *et al*., 2013). Trypanosomosis causes stunted growth in calves, loss in milk yield, loss of working ability and mortality in affected cattle (Maichomo *et al*., 2009). However, understanding of farmers' knowledge and perceptions on the impacts of trypanosomosis and tsetse fly and their participation in developing intervention strategies are prerequisites for their effective implementation (Machila *et al*., 2003; Dransfield and Brightwell, 2004; Sindato *et al*., 2008).

Trypanasomosis was controlled through covering the open spaces in the zero-grazing units with nets by 13.5% of the farmers (Table 27). Netting was an important control mechanism in Kwale County used by 52.4% of respondents compared to only 0.3 in Kilifi County. Restricting cattle in zero-grazing units with fly proof nets resulted in an increase in the annual gross outputs of 5.5% while application of SPPs increased the annual gross outputs by 5.6% (Muraguri *et al*., 2000) in Kwale County. Partial protection as a consequence of semi zero-grazing by 47.7% of the respondents during the day and confinement during the night or incomplete protection due to net damage still appeared to offer some advantages when compared with unprotected animals under free range grazing system. Despite 17.6% of households using trypanocides, Maloo *et al*. (1992b) reported that field studies and on-station experimentation have shown trypanocidal drug prophylaxis to be ineffective in controlling trypanosomiasis in the coastal region. This has major implications for trypanosomiasis control in small-scale cattle in the region.

3.6: Identification of Recommendation Domains in Small-scale Dairy Cattle Farms in Coastal Lowlands of Kenya

3.6.1: Variables used in the Two-Step Procedure

The initial sample had 415 households and after exploratory examination, 33 outliers were eliminated prior to development of the clusters. 31 of the outliers practiced either zero-grazing or semi zero-grazing system with large land sizes and high farming experience. The other 2 outliers were males in single-person clusters who practiced semi zero-grazing system and had large land parcel sizes. In addition, one used concentrate feeds and had high farming experience while the other did not use concentrates and had low experience as a farmer.

After their elimination, a four-cluster solution was developed automatically through the Two-Step cluster method (SPSS, 1989) based on five variables chosen *apriori* from 382 households. The variables used were: sex of household head-HHSEX (1 - male; 2 - female), production system - PSYSTEM (1 - zero grazing system [ZGS]; 2 - semi zero-grazing system [SZGS]; 3 - free range grazing system [FRGS]), concentrates feeding - CONCFEED (0 - No; 1 - Yes), land size in acres - LANDSIZE and farming experience in years - FARMEXP. Two-Step cluster analysis was used to classify the small-scale farmers according to some natural relationships suggested by the data utilized. In the process, individuals are grouped into clusters so that those in the same clusters are more like each other than they are like individuals in other clusters.

3.6.2: The Two-Step Cluster Procedure

The cluster means and significance levels of continuous variables used in Two-Step cluster solution are shown in Table 28. The respondents were classified into clusters such that each household belonged to one and only one cluster. For the whole sample, 30.4, 28.8, 20.6 and 20.2% of the households were classified into clusters 1, 2, 3 and 4 respectively. The importance of clusters predictors also differed across clusters. For the whole sample the most important clusters predictors were the systems of production and concentrate feeding.

Table 28: Cluster means and significance levels of variables for four clusters solution

Variables	Cluster means				Predictor importance	F
	1	**2**	**3**	**4**		
LANDSIZE (acres)	4.53	4.05	4.69	5.37	0.2	25.53
FARMEXP (years)	7.04	7.35	6.90	8.04	0	9.44
PSYSTEM (%)	2.47	1.73	2	2	1.0	34.49
CONCFEED (%)	0	1	1	1	0.8	251.48
HHSEX (%)	1.23	1.28	2	1	0.4	73.60
Cluster (%)	30.4	28.8	20.6	20.2		
n	116	110	79	77		

FARMEXP - farming experience; LANDSIZE - Land size; n- number of respondents; HHSEX - Household head sex (1 - male; 2 - female), PSYSTEM - Production system (1 - zero grazing; 2 - semi zero- grazing; 3 - free range), CONCFEED - Concentrates feeding (0 - no; 1 - yes), all variables significant at P < 0.001).

The categorical variables varied between clusters as shown in Table 29.

Table 29: Frequency of categorical variables in the four clusters solution

Cluster	PSYSTEM (%)			CONCFEED (%)		HHSEX (%)	
	ZGS	**SZGS**	**FRGS**	**Yes**	**No**	**Male**	**Female**
1	10.3	32.8	56.9	0	100	76.7	23.3
2	63.6	0	36.4	100	0	71.8	28.2
3	0	100	0	100	0	0	100
4	0	100	0	100	0	100	0

PSYSTEM - Production system [(1 - ZGS; 2 - SZGS; 3 - FRGS) where ZGS – zero-grazing system, SZGS – semi zero-grazing system, FRGS - free range grazing system]; CONCFEED - Concentrates feeding (0 - no; 1 - yes); HHSEX - Household head sex (1 - male; 2 - female).

In cluster 1, 76.7% of household heads were male, practiced free range grazing system (56.9%) and did not use any concentrate. In cluster 2, 71.8% of household heads were male, practiced zero-grazing system (63.6%) and all used concentrates. Clusters 3 and 4 practiced semi zero-grazing system of production and did not use any type of concentrate. However, all household heads in cluster 3 were female while in cluster 4 all were male.

3.6.3: Validity and Stability of the 4-Clusters Solution

It was necessary to consider the validity and stability of the 4-clusters solution prior to discussing the results of cluster means and significance levels of continuous and categorical variables and frequency of categorical variables for the four groups Two-Step cluster analysis (Table 28 and Table 29). The 382 households left after elimination of the 33 outliers were split into two sub-samples according to counties. Kwale County had 93 households constituting one sample and Kilifi County had 289 households constituting the other sample. These sub-samples were cluster analyzed separately. For Kwale County, before cluster solution was developed 5 outliers were eliminated after further exploratory examination. Of the 5 outliers, 3 were females who practiced free range system and did not use concentrates despite having a lot of farming experience while the other 2 were males who practiced semi zero-grazing system despite having small land sizes and high farming experience.

Cluster means and significance levels of continuous variables for 4-clusters Two-Step cluster procedure for the two counties based on the continuous and categorical variables selected *apriori* were similar across the sites (Table 30). For Kilifi County, 34.9, 28.7, 19.0 and 17.3% and for Kwale County, 33.0, 29.5, 20.5, and 17.0% of the households were classified into clusters 1, 2, 3 and 4 respectively. The characteristics of continuous variables in the clusters were remarkably similar across the the two counties though the actual levels varied. For example, cluster 1 in the two counties was characterized by highest land sizes of 4.33 and 7.8 acres and lowest farming experience of 6.94 and 6.17 years while 2 had lowest land sizes of 3.81 and 3.2 for Kilifi county and Kwale County respectively. These results suggested that the 4-clusters solution was relatively stable and valid, and thus generalizable to the general population.

Table 30: Cluster means and significance levels of variables for 4-clusters solution for Kilifi county and Kwale County

Variables	Cluster means				F	Sig.
	1	2	3	4		
Kilifi county						
LANDSIZE (acres)	4.33	3.81	4.31	4.00	0.480	0.696
FARMEXP (years)	6.94	7.00	8.16	7.04	0.834	0.476
PSYSTEM (%)	2.5	1.98	2.0	2.2	12.72	0.000
CONCFEED (%)	0.0	0.9	1.0	1.0	797.18	0.000
HHSEX (%)	1.4	2.0	1.0	1.0	412.66	0.000
Cluster (%)	34.9	28.7	19.0	17.3	-	-
n	101	83	55	50	-	-
Kwale county						
LANDSIZE	7.84	3.20	7.58	4.02	9.333	0.000
FARMEXP	6.17	8.47	6.62	8.12	1.497	0.221
PSYSTEM (%)	1.0	1.0	2.14	2.0	211.08	0.000
CONCFEED (%)	1.0	1.0	0.93	0.94	0.91	0.440
HHSEX (%)	2.0	1.0	1.0	2.0	-	-
Cluster (%)	33.0	29.5	20.5	17.0	-	-
n	29	26	18	15	-	-

FARMEXP - farming experience; LANDSIZE - Land size; n - number of respondents; HHSEX - Household head sex (1 - male; 2 - female), PSYSTEM - Production system (1 - zero grazing; 2 - semi zero- grazing; 3 - free range), CONCFEED - Concentrates feeding (0 - no; 1 - yes).

These means, univariate F ratios and levels of significance were used to describe and label the clusters. However, the F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal. Therefore, the recipients of cluster solutions should always be wary about the validity of the clusters, as cluster analysis is not based on stochastic foundations.

Majority of households were in cluster 1 (30.4%) (Table 28) and characterized by moderate farming experience (7.04 years), 56.9% practiced free range grazing system of production and

76.7% were male headed. Probably due to this moderate farming experience and free range grazing system of production, none used concentrates. This cluster exemplified a group of producers who relied mostly on grazing natural pastures with no supplementation typical of a low-input low-output system of production.

Cluster 2 had 28.8% (Table 28) of the households and was characterized by smallest land sizes (4.05 acres) and majority (63.6%) kept their cattle under zero-grazing system. Most of them were male-headed (71.8%) and all supplemented their cattle with concentrates. This was an indication of higher level of intensification probably associated with small land sizes and hence necessitating the need for supplementation and ‘cut and carry’ system in order to meet cattle nutritional requirements.

Cluster 3 (20.6%) was characterized by female-headed households who practiced semi zero-grazing system where cattle were partly grazed and at times stall-fed (Table 28). They had the lowest farming experience of 6.9 years and all supplemented their cattle with concentrates. The high level of concentrate use despite the system of production and low farming experience suggested that being new entrants to cattle farming, they can be encouraged to increase their investments in cattle production. This cluster characterized a group of farmers who are in the process of intensification.

Cluster 4 (20.2%) was characterized by male-headed households who practiced semi zero-grazing system where cattle were partly grazed and at times stall-fed (Table 28). However, they recorded the highest levels of concentrate use, land sizes and farming experience. This represented a group of producers though not resource poor as had large parcels of land and adequate knowledge preferred to graze animals rather than stall-feed. Being resource endowed, these large farms had less incentive to intensify since the land availability is higher. However, they should try out various options to maximize their milk output like stall feeding to protect their animals from harsh weather conditions and conserve surplus fodder and thus enhance their productivity.

3.6.4: Partial Validity of the Proposed Cluster Classification

What characteristics might be expected to differ across the 4-cluster groups, given the typology established in Table 28? For instance, for the typology developed to be valid, it can be expected that households in cluster 3 with the lowest farming experience should be the youngest while those in cluster 4 should be the oldest. This created the need to test the partial validity of the proposed cluster classification. The variables used were: household age (HHAGE), price of milk (MILKP), milk income per farm (MILKINC), milk production in litres per cow per day (MILKCOW), number of cattle per farm (TOTCOWS), household head highest education level attained (HHEDUC), household head access to credit for cattle farming (DAIRY CREDIT), household head worked off-farm (HHOFFARM) and hired labour for cattle enterprise (LABHIRE). The last four were dummy variables coded: household head education level attained: 0 - none, 1- primary, 2 - secondary, 3 - technical college and 4 - university and worked off-farm work, had access to credit and hired labour: 1- yes, 2 - no respectively.

The means of the variables used in partial validity check for the proposed cluster classification are shown in Table 31. Except for total number of animals per farm all other variables varied significantly (P < 0.05) across the four clusters. Cluster 1 had the lowest household age, milk production per cow, total number of cattle, milk production and milk income per farm. This was expected as established earlier (Table 28) given they did not supplement their cattle which were kept under free range grazing system. Cluster 2 had the highest milk production per cow and milk income per farm, majority of who were men. Given they had lowest land sizes and majority reared cattle production under zero-grazing system with supplementation, was an indication of high level of investment as it comprised oldest household heads. Hence, they were expected to maximize returns from their investment as majority of them did not work off-farm by producing more milk for sale. Cluster 3 comprised women majority of who did not work off-farm and had no formal education. This was reflected in the hiring of labour as they were available to take care of their cattle. Cluster 4 was composed of men only and had highest number of cattle per farm. In addition, though they had moderate education levels and majority of them did not work off-farm.

Table 31: Partial validity check for the proposed 4-clusters classification

Variables	**Cluster**				
	1	**2**	**3**	**4**	**F**
HHAGE (years)	48.72	52.87	49.10	52.03	4.080
MILKP (Ksh/litre)	42.99	48.60	44.07	44.72	7.547
MILKINC (Ksh/farm)	264.02	538.51	303.56	378.19	11.972
MILKCOW (litres/cow/day)	4.95	6.83	5.31	5.57	6.327
TOTCOWS	3.33	3.65	4.19	4.48	2.351
HHEDUC	1.41	1.99	0.79	1.44	14.077
DAIRYCREDIT	1.93	1.86	1.75	1.92	5.351
HHOFFARM	1.78	1.70	1.96	1.85	7.404
LABHIRE	1.53	1.35	1.71	1.61	9.207

In pursuit of the question of partial validity check for the proposed cluster classification, a discriminant analysis was used to determine the characteristics that differed across the 4 clusters. Discriminant analysis was done using demographic and socio-economic variables not previously considered in the cluster procedure in order to ascertain the profile of each cluster. At this stage, the emphasis was on the characteristics of the clusters after they have been identified. The standardized canonical discriminant functions were used to determine the relative importance of each independent variable in discriminating between the groups.

The standardized canonical discriminant function coefficients, structure matrix and functions and group centriods varied (Table 32).

Table 32: Summary of Standardized Canonical Discriminant Functions

Parameters	**Function 1**	**Function 2**	**Function 3**
Eigen value	0.268	0.118	0.029
% of variance	64.6	28.4	7.0
Canonical Correlation	0.460	0.325	0.167
Standardized Canonical Discriminant Function Coefficients (weights)			
OffFarm	-0.286	0.145	0.330
Hheducation	0.374	-0.058	0.381
DiaryCredo	0.215	-0.629	0.569
Labourhire	-0.278	0.323	0.443
Totalcows	-0.371	0.435	0.460
Milkincome	0.390	0.380	0.069
MilkPrice	0.309	0.352	-0.001
Hhage	0.341	0.215	0.191
Structure Matrix (loadings)			
Hheducation	0.580*	-0.076	0.281
Milkincome	0.577*	0.501	0.116
Labourhire	-0.508*	0.084	0.365
OffFarm	-0.470*	0.226	0.155
MilkPrice	0.456*	0.403	-0.108
DiaryCredo	0.201	-0.606	0.664*
Totalcows	-0.074	0.401	0.536*
Hhage	0.208	0.222	0.249*
Functions at Group Centroids			
1	-0.155	-0.482	-0.040
2	0.742	0.157	-0.061
3	-0.681	0.396	-0.174
4	-0.181	0.157	0.327

**** Largest absolute correlation between each variable and any discriminant function.***

The standardized discriminant function coefficients and structure matrix can be used to determine the relative importance of each independent variable in discriminating between the groups. In the clustering analysis only loadings above ±0.30 should be considered as significant discriminants (Mick, 1990; Hair *et al.*, 1992). Since the variables were standardized in the analysis to 0 and 1 variance, a correlation coefficient or weighting of 1, indicates strong correlation, 0 is neutral and -1 shows strong negative correlations. Negative means indicated levels lower than the overall sample mean. This allowed comparison of different farming systems in terms of resources availability, constraints and opportunities. Discriminant analysis indicated that household head education, off-farm employment, hires labour for dairy enterprise and milk income (Ksh/ farm) were important variables that distinguished the clusters.

For the discriminant model, only two out of the three discriminant functions were significant ($P < 0.001$). The two significant functions 1 and 2 had Eigen-values of 0.26 and 0.12 and percent of variance explained values of 64.6% and 28.4% respectively. In addition, they had canonical correlation of 0.46 and 0.33 respectively and achieved a classification accuracy of 77%. These results suggested a reasonable discrimination has been achieved among the four clusters.

For function 1, household head level of education and milk income (Ksh/farm) had high loads. These variables reflect important characteristics of households who practice free range grazing system of production. Consistent with this, examination of group centroids differentiated between cluster 2 and all the other clusters. Cluster 2 is differentiated from others by its high positive centroid weight while cluster 3 is differentiated from others by its high negative centroid loading. Function 2 had high weights for access to dairy credit and milk income (Ksh/farm). The group centroids suggested that this function distinguished between cluster 1 and all the other clusters, and cluster 3 with clusters 2 and 4. This suggested that milk income (Ksh/farm) and total number of cows per farm were key variables that set apart these two groups of clusters as cluster 2 had the highest milk income.

The results suggest that the automatic 4-cluster solution was relatively stable and valid and thus could be generalized to the general solution. The Two-Step cluster analysis procedure achieved a natural classification using a sample of small-scale crop-livestock producers in Coastal Lowlands of Kenya into small number of mutually exclusive groups based on similarities on demographic and social economic characteristics. These allow researchers, policy makers and development agents to include only farmers belonging to the domains of interest which have the greatest potential for satisfying the pre-determined goals to achieve national development goals of improved livestock production in Coastal Lowlands of Kenya.

3.7: Conclusions

The study found that the mean land size was 5.3 acres while a proportion of 68.4% of respondents owned less than 6 acres. The mean milk yield/cow/day was 5.7 litres with 44% of the farms producing less than 5 litres. The mean herd size was 3.9 and a proportion of 30.7% and 21.4% of the animals were milking cows and heifers respectively. In addition, 61% and 68.9% of respondents owned between 1 - 3 animals and either used concentrates, cereal milling by-products or mineral salts. The use of commercial concentrates is not popular among the small-scale dairy farmers. Incidences of feed shortages were prevalent throughout the year and ranged from 10.1% to 88.2% in October – December and January – March respectively. This low milk production experienced in the study area may be attributed to quality of breeds kept.

Each cluster had unique characteristics which would help define research and development priorities based on factors of production, opportunities and constraints. For instance, livestock intensification strategies such as increased and strategic use of supplements should be appropriate and maybe adopted by producers in cluster 1. In clusters 3 and 4, though headed by females and males respectively, all livestock were reared under semi zero-grazing system with concentrates supplementation. Farmers with the smallest land size and high ratios of number of cows per acreage were the most intensified while those with the largest land size were the least intensified. In clusters 1, 3 and 4 emphasis should be placed on housing cattle through adoption of zero grazing system which has benefits as shown by cluster 2 by way of increased milk production. The use of concentrates by producers in clusters 2, 3 and 4 was suggestive of producers who had adequate knowledge in cattle production and used supplements.

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4.0: CHEMICAL COMPOSITION AND RUMEN DEGRADATION KINETICS OF COMMON ROUGHAGES IN COASTAL LOWLANDS OF KENYA

4.1: Introduction

The ability of a feed to sustain animal performance depends mainly on its digestibility. Feed digestibility is influenced by its chemical and physical characteristics, as these properties affect capability of digestive enzymes to colonize and digest the feed particles (Kitessa *et al*., 1999). Digestion of feed in the rumen (disappearance of feed entities in the rumen) is the result of two competing processes: degradation and passage (Mertens and Ely, 1982). Degradation occurs through the activity of microorganisms in the rumen, although in fresh forages, plant-derived proteinases may contribute to the first stages of protein degradation (Attwood, 2005). The passage rate determines the time the feed is retained in various components of the gastro-intestinal tract for digestive action.

Complex relationships among plant components, microorganisms in the rumen and the animal are involved in the utilization of forages by animals. Although each of these factors can individually impose some limits upon forage utilization, both digestibility and intake of forage are a result of the dynamic interaction of the plant, microbes and animal (Mertens and Ely, 1982). Different techniques have been used to evaluate the digestibility of feeds in ruminant animals. These techniques are: (i) *in vivo* methods which involve the direct use of the animals (Johnson, 1966; Rodríguez, 1968), (ii) *In sacco* (mobile nylon bag method) technique where feed is digested while contained in a nylon bag inserted in the rumen ((Ørskov *et al*., 1980). (iii) *in vitro* laboratory methods, which do not require the use of animals and simulate rumen environment and digestion process using rumen fluid collected from donor animals (Tilley and Terry, 1963) or estimation of gas production (Menke *et al*., 1979; Menke and Steingrass, 1988).

The *in sacco* method using nylon bags can be used for the prediction of digestible dry matter and animal performance (Ørskov *et al*., 1980). The outcome from this method is affected by a number of potential sources of variation such as porosity of the bag material, sample weight to surface area ratio, donor animal and its diet, retention time, size of bag and microbial contamination of the residue (Cherney *et al*., 1993; Kempton, 1980). Although loss from the bag may not necessarily relate to protein absorption, the technique seems to be very useful in predicting intestinal digestibility (Stern *et al*., 1997). The objectives of this study were: (i) determine chemical composition (ii) assess *In Vitro* Dry Matter Digestibility (IVDMD) and (ii) determine the rumen degradation kinetics of dry matter and protein using *in sacco* nylon bag technique of roughages commonly used in Coastal Lowlands of Kenya.

4.2: Materials and Methods

4.2.1: Study Area

The study was conducted in the Coastal Lowlands of Kenya (Kwale and Kilifi counties) which fall in over five agro-ecological zones characterized by different climatic, topographic, soil, and other environmental features that influence the potential of agricultural development (Jaetzold and Schmidt, 1983). The study area is described in detail in section 3.2.1.

4.3: Data Collection

4.3.1: Longitudinal Survey

A longitudinal survey was carried out from June 2012 - June 2013 using a checklist (Appendix 7.4). It covered a purposive sample of 32 farms from the main survey sample described in section 3.2.2. Of the 32 households, 13 were from Kwale county and 19 from Kilifi county. The farms were selected based on the following criteria: zero-grazed or semi zero-grazed milking cow(s) in early lactation, ability to keep records and willingness to participate in the study. Detailed farm data on feed production, type of feed, animal feed intake and performance (milk yield, live weight change) were collected every two weeks by trained enumerators. Prior to commencement of data collection, farmers were trained on how to sample feeds, measure milk yield and weigh feeds offered to animals.

4.3.2: Laboratory Analyses

4.3.2.1: Samples Preparation

The two samples collected per fodder plot were chopped, thoroughly mixed and divided into two portions upon delivery to KARLO-Mtwapa laboratory: one portion for DM and the other for nutritive value determination. A total of 780 samples from 26 forage and crop residue types and 74 concentrate samples from 4 concentrate types were collected. The forage and crop residue samples were categorized according to season of collection: seasons I, II, III and IV described earlier. Due to their low frequency of occurrence and use as feed and the high cost of nutrient analysis, 274 samples from 16 forage types were not analysed. Thereafter, samples of the same forage type from the same farm and /or location were combined, thoroughly mixed and then sub-sampled resulting in 142 out of 506 samples from 10 types for laboratory analysis. These were two weeds: *Asystacia gangetica* and *Commelina benghalensis:* seven pasture grasses: *Cynodon plectostaychus* (star grass), *Panicum maximum* (guinea grass), *Panicum coloratum* (coloured guinea), *Zea mays* (maize stover), *Pennisetum purpureum* (napier grass), *Rottboelia exaltata*, and natural pasture grasses mixture and one tropical browse shrub: *Leucaena leucocephala*. Samples of the same concentrate type from the same farm and/or location were combined, thoroughly mixed and then sub-sampled resulting in 32 samples of 3 types of concentrates. These were: maize bran (9 samples), maize germ (13 samples) wheat bran (6 samples) and poultry litter/manure (4 samples).

4.3.2.2: Dry Matter (DM) and Chemical Composition Determination

The DM was determined by oven-drying at 105°C for 12 hours. The chemical composition determination feed samples were oven dried at 60°C for 24 hours and then ground in a Willey mill to pass through a 2mm screen and stored in nylon zip lock bags. The organic matter (OM) was determined through dry-ashing in a muffle furnace for 4 hours at 500°C. The chemical composition of the 142 forage samples was analyzed using Rugged Near-IR spectrometer (NIRS) using MPA integrating sphere (Bruker Optics, 2013). Before scanning the samples were pre-dried at 60^{o}C overnight in an oven to standardize moisture conditions.

4.3.2.3: In Vitro Dry Matter Digestibility (IVDMD)

In vitro dry matter digestibility was determined following the methods of Tilley and Terry (1963) by incubating 5g of sample in thermostatically controlled water bath t a38^{o}C. 500 ml of rumen liquor was obtained from the rumen of a cannulated steer fed on Rhodes grass hay and grazed on natural pastures at the University of Nairobi, College of Agriculture and Veterinary Sciences farm. All samples were incubated in duplicates. IVDMD was calculated as follows: [1 - (DM residue - blank DM) / DM original)] × 100, where DM residue is the DM recovered after 96 hours of fermentation, blank DM is the DM recovered in the corresponding blank incubated with rumen fluid after the same fermentation time, and DM original is the DM of the substrate placed in the tube (Madrid *et al*., 2002).

4.3.2.4: In Sacco Dry Matter and Crude Protein Disappearance and Degradation

In sacco nylon bag technique was used to determine DM and CP degradation (Ørskov and McDonald, 1979) with nylon bags of pore size 40 µm (inner diameter: 6.5 x 12 cm). Two ruminally fistulated steers fitted with permanent cannulae at University of Nairobi, College of Agriculture and Veterinary Sciences farm were used in this study. The steers were fed on Rhodes grass hay and grazed on natural pastures. Water was provided ad lib. Approximately 5g of the sample was weighed into labeled nylon bags in duplicates which were securely tied with a knot at the end using a fishing line. The bags were anchored in the rumen with a 60cm length of nylon rope in batches of 12 samples per animal. All samples were incubated in duplicates and withdrawal was timed to give incubation times of 6, 12, 24, 36, 48 and 72 hours. After the specific incubation periods, the bags were retrieved from the rumen and washed immediately under running cold tap water until the rinse water was clear. Thereafter, the bags were oven dried at 70°C for 48 hours to constant weight to determine the weight of nylon bag and dry sample. Zero hour control bags dry matter loss was determined by soaking samples in nylon bags in warm water (approx. 37°C) for 1 hour followed by washing and drying at 70°C for 48 hrs to constant weight. The residues were analyzed for CP and DM content using Rugged Near-IR spectrometer (NIRS) using MPA integrating sphere (Bruker Optics, 2013). DM and CP losses for each incubation time were computed as the difference between the pre-incubated and post-incubation samples.

4.4: Statistical Analyses

The data obtained from *in vitro* dry matter digestibility was subjected to one-way analysis of variance (ANOVA) procedure using the SAS program General Linear Model procedure (SAS, 1999). Significant means were compared using the Duncan's Multiple Range Tests.

The data generated *in sacco* was managed in Ms. Excel 2003 and analyzed using NEWAY computer software (Chen, 1995) which was used for estimating the ruminal degradation kinetics and curves by fitting them into the non-linear equation (Ørskov and McDonald, 1979), revised by McDonald (1981), with simultaneous estimation of lag phase as proposed by Dhanoa (1988):

$P = a + b\,(1 - e^{-c\,(t-L)})$, $t \geq L$: where,

'P' = potential degradation (%) of the nutrient components under investigation after time't';

'a' = the water soluble fraction (%) or intercept at Y-axis representing the portion of DM or CP solubilized at initiation of incubation (time 0);

'b' = the fraction of DM or CP (%) that is insoluble but potentially degradable in the rumen,

'a+b'= the potential degradability (%) or the upper asymptote;

'c' = the rate of degradation (%/hour) of the rumen degradable fraction 'b';

't' = time of incubation (hours) and

'L' = Lag phase (hours).

The Effective Degradability of Dry Matter (EDDM) or of Crude Protein (EDCP) was calculated using the outflow rates of 0.02, 0.05 and 0.08/hour (Ørskov *et al*., 1980), with simultaneous estimation of lag phase as proposed by Dhanoa (1988):

EDDM or EDCP = a + [bc/(c+k)] e^{-kL} where,

ED = effective degradability and 'a', 'b', 'c' and L are the constants as described earlier in the non-linear equation above and 'k'= the estimated rate of outflow from the rumen (0.05/hour).

The data obtained for *in sacco* DM and CP disappearance, degradation characteristics and effective degradability were subjected to one-way analysis of variance (ANOVA) procedure using the SAS program General Linear Model procedure (SAS, 1999). Significant means were compared using the Duncan's Multiple-range Tests. This was done according to the following model:

$Y_{ij}=\mu+\delta_{ij}+\varepsilon_{ij:}$ where:

Y_{ij} = the criteria under study, μ = overall mean, δ_i = type of feed effect, and ε_{ij} = residual.

4.5: Results and Discussions

4.5.1: Chemical Composition of Common Roughages in Coastal Lowlands of Kenya

The mean chemical composition of common roughages in the study area varied as shown in Table 33.

Table 33: Chemical composition (g/kg DM) of common feed resources

Roughages	DM (g/kg)	CP	Ash	CF	Fat	NDF	ADF
Weeds							
A. gangetica	273.4±72.6	131.8±26.7	127.6±8.8	282.5±22.0	12.2±10.5	493.4±50.5	385.8±22.9
C. benghalensis	168.5±59.8	162.7±22.6	117.3±14.7	284.1±17.0	31.9±11.9	403.8±53.7	386.8±34.2
Crop residues							
Maize stover	587.2±179.8	72.2±10.4	88.0±11.5	345.7±22.8	0.0	721.1±52.7	438.0±29.7
Maize forage	389.0±155.1	112.8±13.6	107.1±21.8	319.5±15.3	0.41±1.1	676.6±46.7	419.0±17.7
Planted fodder							
Napier grass	227.5±90.5	86.4±11.3	135.6±24.2	337.7±12.0	0.1±0.2	716.6±40.4	455.4±18.1
Pasture grasses							
P. maximum	274.3±78.4	85.7±7.9	97.2±0.3	351.7±17.1	0.0	724.8±45.1	461.2±19.6
P. coloratum	264.7±94.7	85.2±6.6	112.5±14.4	342.6±13.2	0.0	675.5±56.6	478.4±17.3
C. plectostaychus	466.7±171.5	84.5±6.7	82.0±12.4	344.1±14.8	0.4±0.7	723.1±51.1	477.3±21.4
R. exaltata	367.7±153.7	97.1±13.5	117.8±18.9	320.5±21.6	1.1±3.0	671.4±72.8	456.2±21.2
Natural pastures	369.0±199.5	84.1±10.9	113.7±14.7	323.0±13.9	3.8±5.4	603.8±57.0	454.6±19.5
Tropical browse shrub							
L. leucocephala	372.8±74.0	270.8±39.1	99.2±5.7	199.7±32.4	71.8±16.5	333.6±72.1	357.4±55.1

DM - dry matter; CP - crude protein; CF - crude fibre; OM - organic matter; NDF - neutral detergent fibre; ADF - acid detergent fibre.

There were considerable variations in chemical composition between the roughages. *C. benghalensis* and maize stovers had a DM of 168.5 and 587.2 g/kg DM for respectively while that of *L. leucocephala,* a tropical browse shrub was 372.8 g/kg DM. The CP ranged from 72.2 - 270.8 g/kg DM for maize stovers to *L. leucocephala* respectively. The NDF and ADF ranged from 333.6 - 724.8 g/kg DM and 357.4 - 478.4 g/kg DM for *L. leucocephala* and *P. maximum* and *L. leucocephala* and *P. coloratum* respectively. The CF content ranged from 199.7 g/kg DM for *L. leucocephala* to 351.7 g/kg DM for *P. maximum. C. plectostaychus* had the lowest ash content (82.0 g/kg DM) while *A. gangetica* had the highest (127.6 g/kg DM). *L. leucocephala* had highest fat and CP contents of 71.8 and 270.8 g/kg DM and lowest CF, NDF and ADF contents. The variations in chemical composition within and between forages could be attributed to conditions of soil, stage of maturity at harvest, forage species, variety or hybrid and weather conditions (Ravindran and Ravindran, 1988; Hoffman *et al*., 1993**;** Shaver *et al*., 2002).

L. leucocephala was fed as a mix of leaves and twigs and had a CP content of 270.8 g/kg DM (Table 33) which was higher than 242 and 244 g/kg DM for leaves and twigs reported by Ndikumana and de Leeuw (1993) and Mlay *et al*. (2006) respectively. However, it was comparable to 276 g/kg DM despite been harvested at the peak of dry season (Babayemi 2007) and 268 g/kg DM of leaves harvested at 12 weeks interval (Edwards *et al*., 2012). This showed that the protein content does not change with leaf maturity even when they dry and fall to the ground (Leng, 1992). Kariuki (1998) reported a CP content of 216 g/kg DM while Njarui *et al.* (2003) reported a CP content of 237.3g/kg DM. However, the ash and NDF values were similar to 87.5 and 339 g/kg DM respectively reported by Njarui *et al.* (2003). *L. leucocephala* fat content of 71.8 g/kg DM was lower than 43.6 g/kg DM for whole plant and comparable to 70.7

g/kg DM for leaves respectively reported by Ndikumana and de Leeuw (1993). *L. leucocephala* ash content was 99.2 g/kg DM which was higher than 62.7 g/kg DM for whole plant reported by Ndikumana and de Leeuw (1993) but lower than 134 g/kg DM reported by Mlay *et al*. (2006).

High CP content ranging from 14 to 29 g/kg DM (Devendra, 1990; Topps, 1992) of fodder trees and shrubs (like *L. leucocephala*) is an important nutritional aspect. They can supplement poor quality grass and crop residues as they possess high levels of protein, vitamins and minerals (Paterson *et al*. 1998; Adjolohoun *et al*., 2008). They are also available during the dry season making them a cheap and valuable feeding resource to supply the much needed protein. This could be attributed to their nitrogen fixing and relatively deep root systems giving them drought resistance (NFTA, 1987). Consequently, as a means of increasing yields of DM and CP in small-scale farms, efforts have been directed to introducing multi-purpose trees like *Leucaena* sp. *Gliricidia* sp. and *Calliandra* sp. in alley cropping systems and around the homestead in the coastal region (Abdulrazak *et al.*, 1996; Juma *et al*., 2006). Utilization of tropical browse species like *L. leucocephala* is limited by presence of anti-nutritional factors generated in natural feedstuffs through normal metabolism of species and by different mechanisms (Norton, 1994; Nguyen *et al*., 2002). Complex phenolic compounds (tannins and flavanols) are widespread, abundant and appear to be the major constraint of some leguminous plants because of their effect on intake, digestibility and animal metabolism (Kumar and Singh, 1994).

Maize stover had an ash content of 88.0 g/kg DM which was comparable to 93 g/kg DM reported by Weyongo *et al*. (2004) but lower than 132.4 g/kg DM reported by Osuga (2008). Ash content is an indicator of total inorganic materials in feeds and can have a significant impact on the estimation of available energy as it does not contribute to the energy value of feeds. The ash value can sometimes provide an indication of feeds contamination with soil (Mertens, 2000).

Maize stover had a CP content of 72.2 g/kg DM while maize forage had 112.8 g/kg DM (Table 33). The maize forage in this study was cut from the fields immediately after cobs were harvested and as a result had high moisture content of 611 g/ kg compared to maize stover of 412.8 g/ kg, an indication that the latter may have been at an advanced stage of growth. Crowder and Chedda (1982) indicated that advanced maturity is accompanied by an increase in cell wall and a decrease in cell contents and results in lower CP. The maize stover CP content (72.2g/kg DM) was higher than 46 g/kg DM (Ondieki *et al*., 2013), 52.0 g/kg DM (J*uma et al.,* 2006) and 53.3 g/kg DM (Osuga, 2008) respectively. However, the CP was comparable to 71 and 78.6 g/kg DM reported by Weyongo *et al*. (2004) and Kamala *et al*. (2005) respectively.

The low CP of maize stover could be attributed to the stage of harvesting and storage. Field observations showed that the most common observed methods of handling maize stovers were harvesting and storing under trees or in the homestead in barns that were not roofed or stacking in open fields for gradual collection as required for feeding. These methods exposed the maize stovers to vulgarities of weather and leaf shattering leading to loss of considerable amounts. In this study, most of maize was harvested at post hard grain stage and as a result most of maize stover available to farmers was of low quality.

Napier grass had a CP content of 86.4 g/kg DM (Table 33) which was higher than 46.3, 64 and 79 g/kg DM reported by Njarui *et al*. (2003), Muinga *et al*. (1995) and Abdulrazak *et al*. (1996)

in the coastal Kenya region respectively. However, it was comparable to 86.3 and 90.0 g/kg DM reported by Ansah *et al*. (2010) and Snijders and Wouters (1990) respectively. The CP content was lower than 103.8 g/kg DM (Ndikumana and de Leeuw, 1993), 107.0 g/kg DM (Mbuthia and Gachuiri, 2003) and 114 g/kg DM (Babayemi, 2007). On Kenyan farms, a mean CP content of 76.0 g/kg DM has been reported (Wouters, 1987). Napier grass had ash and NDF contents of 135.6 and 716.6 g/kg DM which were comparable to 134 and 721.4 g/kg DM and 136 and 703.0 g/kg DM reported by Njarui *et al*. (2003) and Mlay *et al*. (2006) respectively. Ansah *et al*. (2010) reported lower ash content (55.0 - 71.4 g/kg DM) and comparable NDF levels (686.0 - 765.1 g/kg DM) for napier grass. However, the ash content was lower than 162.7 g/kg DM reported by Osuga (2008). The wide variation across references can be attributed to the stage of harvesting. Napier grass maturity is associated with a decline in CP and an increase in DM yield (Humpreys, 1991; Cherney *et al*., 1993). As napier grass matures, the leaf: steam ratio declines causing a change in the chemical composition with concomitant reduction in feeding value (Minson, 1990). The CP in napier grass has been found to decline from 200 - 50 g/kg DM (Muia *et al*., 1999) and 109.9 to 79.9 g/kg DM (Ansah *et al*., 2010) from 3 - 15 weeks and 60 - 120 days of age respectively. However, the rate of CP decline in napier grass is more rapid in stems than in leaves (Brown and Chavulimu, 1985).

In the study, the pasture grasses were harvested at different stages of growth based on availability rather than maturity, hence the wide range in CP and CF figures observed. The CP and CF of pasture grasses ranged from 84.1 - 97.1 g/kg DM and 320.5 - 351.7 g/kg DM respectively. However, the CP was above the range (72 - 82 g/kg DM) reported by Kariuki (1998) for *P. clandestinum, C. plectostaychus, P. maximum, Chloris gayana* and *Tripsacum* *laxum*. *R. exaltata* had the highest CP and ash content of 97.1 and 117.9 g/kg DM while natural pasture grasses mixture had the lowest ADF and NDF content of 454.6 and 603.8 g/kg DM respectively. *P. maximum* had a CP content of 85.7 g/kg DM which was higher than 79 g/kg DM reported by Babayemi (2007). The difference in chemical composition could be attributed to the season of harvesting as the latter was harvested at the peak of dry season, between the months of February and March. The pasture grass species CP was within range of 30 - 150g/kg DM and more than 50 g/kg DM of very mature grasses (Devendra, 1995). The fat content ranged from 0.4 g/kg DM for *C. plectostaychus* to 3.8 g/kg DM for natural pastures grasses mixture. *P. maximum* and *P. coloratum* had negligible fat levels in this study but Ndikumana and de Leeuw (1993) reported fat levels of 32.3 g/kg DM in *P. maximum*. The presence of fat in these pasture grasses could be attributed to presence of seeds which are rich in oils. *P. coloratum* and *P. maximum* had similar chemical composition except NDF where the latter had a lower value. The CF value for the two grasses was comparable to 357 g/kg DM for the same grasses (FAO, 2003).

Chemical composition is a major determinant of animal production from tropical grasses (Minson, 1990) and could affect ruminant performance at both plant and animal levels. The nutritive value of the forages is a function of morphology, physiology and chemical composition. The chemical composition could vary to greater or lesser extent, according to the growth stage and environmental conditions during growth (Lanyasunya *et al*., 2006c). As a result important differences exist in changes in nutrient quality associated with increased maturity in tropical forages (Arthington and Brown, 2005). The increase in age of grasses is negatively associated with CP content (Minson, 1990; Norton, 1981). Natural pasture grasses differ in quality and quantity fed and in the extent and rate of rumen degradation and hence influence the yield of fermentable substrate (Kariuki, 1998). In addition, the forage species could affect voluntary feed intake and milk yields or body weight changes.

The CP content of the two weeds, *A. gangetica* and *C. benghalensis* was higher than all the other forages except the *L. leucocephala.* They had high CP and low NDF compared to pasture grasses as most of the pastures were harvested at advanced maturity stage. Thus these weeds which grow naturally can and are indeed being used to supplement conventional feed resources both during the wet and dry seasons. *C. benghalensis* had a CP content of 162.7 g/kg DM which was comparable to 177.1 g/kg DM for *C. diffusa* (Lanyasunya *et al*., 2006a) but higher than 133.5 g/kg DM for *C. benghalensis* (Lanyasunya *et al*., 2007). *C. benghalensis* had the highest moisture content of 831.5 g/kg. Wilson (1981) observed that the stems of *Commelina* species have high moisture content and once it is well rooted the plant can survive for long periods without moisture.

According to Leng (1990), forages are considered of low quality if they have less than 80 g CP /kg DM, this being the critical level below which voluntary intake of tropical forages is limited and high quality if having 100 g CP /kg DM and above. Based on these criteria, *L. leucocephala*, maize forage, *A. gangetica* and *C. benghalensis* had nearly 1 to 3 fold CP levels above 80 g/kg DM, and can be considered as medium to high quality forages in study area. Napier grass and pasture grasses had CP content of more than 80 g/kg DM but less than 100 g/kg DM and may be considered as marginal sources of CP. Maize stover had a CP content of 72.2 g/kg DM and therefore of low quality. However, the CP content of the diet should be 120 g/kg DM if moderate production in dairy cattle is to be attained (ARC, 1984). However, though some of the roughages had less than 80 g/kg DM CP, they are seldom fed exclusively alone and the mixtures used provided the required CP content.

Deficiency of protein can be a major limitation to the intake and utilization of most tropical forages due to rapid growth and maturity during the wet season (Minson, 1990). Norton (1981) reported that the minimum CP content required for lactation and growth in cattle is 150 g/kg DM while Van Soest (1994) suggested a minimum requirement of 75 g/kg DM for adequate rumen function. Feeds containing less than 60 g CP /kg DM are considered as CP deficient. Such feed cannot provide the minimum level of ammonia (50 - 80 mg/l) required for maximum microbial growth (Hoover, 1986). In the study area, the CP content of the roughages was adequate to meet the requirements of the host animal and rumen microbes. As such, depending on the roughage fed, they are able to satisfy CP requirements of livestock animals ranging from mature beef cows (70 g/kg DM) (NRC, 1984) to high producing dairy cows (152.0 g/kg DM) (NRC, 2001).

Lanyasunya *et al*. (2006a) illustrated a correlation between age at harvest as influenced by precipitation and nutritive value in commonly used forages in Kenya. There is also a decline in protein content in tropical grasses as the wet season progresses (Sibanda, 1984). In contrast, fibre content increases as the season progresses. The low CP and high fibre content limit the utilization of tropical grasses by ruminants (Lindberg *et al*., 1984). In addition, the vitamins and minerals may limit production, often at chronic levels but the response is often slow and they can normally be economically supplied as supplements in low levels when deficient in available feedstuffs (Coleman and Moore, 2003).

4.5.2: Chemical Composition of Common Cereal Milling By-products in Coastal Lowlands of Kenya

The chemical composition of cereal milling by-products and poultry litter used in the study area is shown in Table 34.

Table 34: Chemical composition (g/kg DM) of maize bran, maize germ, wheat bran and poultry litter

Parameters	Maize bran	Maize germ	Poultry litter	Wheat bran
DM (g/kg)	909.2±0.83	908.8±1.06	911.6±0.49	909.6±0.38
CP	129.3±15.2	104.4±14.1	116.7±0.12	161.6±15.4
Ash	59.9±6.4	58.9±8.4	215.3±7.42	73.4±4.1
CF	97.2±19.7	79.2±19.0	337.2±83.6	104.6±9.4
Fat	49.8±24.9	78.8±16.8	0	44.8±7.3
Starch	271.2±52.9	328.7±52.3	0	135.0±34.3
OM	940.1±6.4	941.1±8.4	784.7±7.42	928.3±1.1

DM- dry matter; CP-crude protein; CF-crude fibre; OM-organic matter.

There was considerable variation in chemical composition of different concentrates. The DM and CP contents ranged from 908.8 - 911.6 g/kg DM and 104.4 - 161.6 g/kg DM respectively. The CF content ranged from 79.3 - 337.2 g/kg DM while the ash and organic matter contents ranged from 58.9 - 215.3 g/kg DM and 784.7 - 941.1 g/kg DM respectively. Maize germ had the highest fat and starch levels which could be attributed to the presence of endosperm mixed with the germ. The maize bran, wheat bran and maize germ DM, CP and OM were similar to 867, 135 and 922 g/kg DM reported by Juma *et al*. (2006) in coastal lowlands respectively. In the study area, maize germ and maize bran are used interchangeably and may be referring to the same thing. The differences in their composition could be attributed to the source and method of extraction. In some cases maize bran referred to as local bran sourced from local 'posho' mills is usually contaminated with maize flour.

Poultry manure had CP of 116.7 g/kg DM which was lower than 154 g/kg DM and organic matter content of 858 g/kg DM was higher than 784.7 g/kg DM reported by Lanyasunya *et al*. (2006b) on small-scale farms in Kenya. Poultry manure/litter has been reported to contain high level of crude protein (150 - 380 g/kg DM) (Trevino *et al*., 2002; Mlay *et al.*, 2005; Lanyasunya *et al*., 2006b). It had a CF content of 337.2 g/kg DM which was within range (110 – 520 g/kg DM) reported by Trevino *et al*. (2002) and Mlay *et al.* (2005). The high and variable CF content was due to contamination with wood shavings used as poultry beddings. Use of bedding materials such as chopped maize stovers and dried pasture grasses that are degradable in the rumen could also improve the overall feeding value of poultry manure. It was observed that despite its high CP content, its use in small-scale farms was very low in agreeement with Lanyasunya *et al*. (2006b).

The poultry production system practiced in coastal region is based mainly on scavenging indigenous poultry with mean flock size of 11.6 birds per farm with a range of 0 – 84. Given then their small flock size per farm and the system of production, their potential manure production is very low. In this study, only 4 households kept broilers (total=3,000; range =200-1500) and 7 kept layers (total = 3,605; range = 100-1000). This could be attributed to low economic status of majority of small-scale farm households in this region as a primary obstacle to increased poultry production. Sufficient poultry manure for ruminant feeding can only be obtained where intensive commercial poultry production is practiced by many farmers. The indigenous chicken was preferred due to their tolerance to diseases and low nutritional requirements. The high ash content of poultry manure of 215.3 g/kg DM could be due to contamination with sand in the study area and therefore may not translate to high total mineral content.

The species composition of natural pastures in the study area is shown in Table 35.

Table 35: Proportionate species composition of natural pastures

Natural pastures composition	**Proportion (%)**
Cynodon plectostaychus	38.7
Panicum maximum	20.8
Panicum coloratum	17.3
Rottboelia exaltata	14.2
Commelina benghalensis	9.1

The dominant grasses in the natural pastures were *C. plectostaychus* (38.7%) and *P. maximum* (20.8%) with *R. exaltata* having the lowest occurrence (14.2%. *C). benghalensis* which is a common weed in pasture fields had 9.1% occurrence. This pasture grasses mixture had a DM and CP content of 369 g/kg and 84.1 g/kg DM respectively (Table 33).

4.5.3: *In Vitro* Dry Matter Digestibility (IVDMD) of Common Roughages in Coastal Lowlands of Kenya

The mean IVDMD of common roughages in the study area are shown in Table 36. There were significant differences ($P < 0.05$) in the IVDMD between some of the roughages. *C. benghalensis* had the highest IVDMD and was different ($P < 0.05$) with all the others except *A. gangetica*. Napier grass had an IVDMD of 40.3% which was lower than 50.4% and 62.9% reported by Njarui *et al*. (2003) and Abate and Abate (1991) respectively. In well fertilized fields, an IVDMD of 65 – 79% for the dwarf napier grass was reported by Chaparro and

Sollenberger (1997). The difference could be attributable to the stage of maturity at harvesting as napier grass was usually cut from the field for feeding as required.

Table 36: In Vitro Dry Matter Digestibility (% DM) of common roughages

Roughages	Mean	Std. Deviation
Weeds		
A. gangetica	56.8[ab]	6.94
C. benghalensis	63.3[a]	4.06
Crop residues		
Maize stover	39.1[c]	1.45
Maize forage	52.9[b]	5.30
Planted fodder		
Napier grass	40.3[c]	4.06
Pasture grasses		
Panicum maximum	41.4[c]	2.01
Panicum coloratum	44.7[c]	5.48
Cynodon plectostaychus	41.6[c]	6.51
Rottboelia exaltata	41.7[c]	5.27
Natural pastures	40.3[c]	7.31
Tropical shrub		
L. leucocephala	54.3[b]	1.61

[a] ***Means with different superscripts within a column are significantly different (P < 0.05).***

Maize stover and maize forage IVDMD were significantly different ($P < 0.05$). Maize stover had an IVDMD of 39.1% which was lower than 49.3% and 49 - 51.6% reported by Juma *et al*. (2006) and Abdulrazak *et al*. (1997) respectively. The difference could be attributable to the storage methods. In this study, maize stover was kept in heaps in the fields, homesteads, under trees open and poorly constructed barns which contributed to their low quality due to loss of leaves and attacks by ants. Natural pastures had an IVDMD of 40.3% which was higher than 34.1% reported by Njarui *et al*. (2003). This difference could be attributed to composition of natural pastures mixture. In Njarui *et al*. (2003), the dominant grasses in the natural pastures were *Themeda triandra*, *Cenchrus ciliaris*, *Chrolis gayana* and *Cynodon dactylon.* In this study the dominant grasses in the natural pastures were *C. plectostaychus, P. maximum, P. coloratum* and *R. exaltata* (Table 35).

C. benghalensis, A. gangetica, *L. leucocephala* and maize forage had IVDMD higher than 45% which, according to Youngquist *et al*. (1990), is the level needed for maintenance of cattle in the tropics. Due to this higher digestibility, they can be used as feed by cattle in the study area for both maintenance and some level of productivity. However, when farmers harvest the roughages for feeding, they do not separate them but were usually fed as mixtures in different combinations. As a result, the high nutritive value of *C. benghalensis*, *A. gangetica*, *L. leucocephala* and maize forage is diluted by those with low crude protein, low IVDMD and high fibre content. In addition, utilization of *L. leucocephala* as animal feed is constrained by presence of anti-nutritional factors (Kumar, 2003).

The variations in dry matter loss may be related to the differences in chemical composition (Aman and Nordkvist, 1983) or to variations in physical structure, such as the distribution within the tissues of lignified cells (Ramanzin *et al.,* 1991). The low protein levels in mature tropical grasses have been reported as one of the major factors contributing to poor digestibility and animal performance (Preston and Leng, 1987; Mlay *et al.,* 2001). *A. gangetica*, *C. benghalensis, L. leucocephala* and maize forage had higher CP (Table 33) and IVDMD (Table 36) than pasture grasses, napier grass and maize stover. These forages also had low CF content which ranged from 199.7 - 319.5 g/kg DM (Table 33). Van Soest (1994) indicated that the CF is the main factor limiting the digestibility in forages. *A. gangetica* and *C. benghalensis* were weeds within food crops fields where manure and fertilization were applied. Pasture grasses and napier grass fields were poorly maintained with no weeding and fertilization application.

4.5.4: *In Sacco* Dry Matter and Crude Protein Degradability of Common Roughages in Coastal Lowlands of Kenya

4.5.4.1: DM Disappearance and Degradation Characteristics

The DM disappearance at different incubation times of common roughages varied as shown in Table 37.

Table 37: DM disappearance (%) at different incubation times for common roughages

Roughages	**Incubation periods (hours)**						
	0	**6**	**12**	**24**	**36**	**48**	**72**
Weeds							
A. gangetica	17.5^{bc}	23.8^{bc}	30.5^{bc}	37.6^{b}	41.9^{abc}	47.8^{abc}	53.2^{bcd}
C. benghalensis	21.5^{ab}	28.5^{ab}	32.7^{ab}	37.4^{b}	46.8^{a}	52.7^{ab}	57.7^{abc}
Crop residues							
Maize stover	12.9^{cd}	21.8^{cd}	24.2^{d}	28.2^{cd}	36.7^{cde}	41.5^{cde}	45.3^{efg}
Maize forage	15.0^{c}	27.6^{b}	31.3^{b}	32.9^{bc}	44.7^{ab}	47.2^{bcd}	58.8^{ab}
Planted fodder							
Napier grass	16.6^{c}	22.1^{c}	25.2^{d}	30.7^{cd}	$39.4b^{bcd}$	43.6^{cde}	47.9^{def}
Pasture grasses							
P. maximum	8.1^{e}	17.0^{d}	18.7^{e}	25.9^{d}	32.8^{de}	36.6^{ef}	39.0^{g}
P. coloratum	8.1^{e}	19.3^{cd}	22.3^{de}	25.2^{d}	33.8^{de}	37.7^{ef}	41.7^{fg}
C. plectostaychus	16.9^{bc}	19.2^{cd}	21.2^{de}	27.1^{cd}	30.2^{e}	34.6^{f}	39.4^{g}
R. exaltata	9.1^{de}	20.8^{cd}	25.2^{d}	29.2^{cd}	35.6^{cde}	43.1^{cde}	50.9^{cde}
Natural pastures	14.0^{c}	22.2^{c}	26.2^{cd}	29.5^{cd}	35.1^{cde}	40.8^{def}	45.2^{efg}
Tropical browse shrub							
L. leucocephala	24.6^{a}	32.9^{a}	35.9^{a}	43.1^{a}	46.0^{a}	54.3^{a}	61.5^{a}
S.D	**5.49**	**5.01**	**5.54**	**6.37**	**6.79**	**7.10**	**8.24**

^{a} Means with different superscripts within column are significantly different ($P < 0.05$). S.D is the standard deviation.

There were significant variations in the amount of DM disappearance between the roughages ($P < 0.05$). Many factors such as stage of maturity **(**Stallings *et al*., 1991**),** forage species **(**Janicki and Stallings, 1988; Nocek and Grant, 1987) and preservation method (Petit and Trcmblay 1992; Tamminga *et al*., 1991**)** influence the digestibility of roughages. For all roughages, there was an increase in DM disappearance with the increased time of incubation. The DM disappearance at zero time represents the readily soluble fraction of the plant material which immediately disappears when feed enters the rumen. This wash fraction (assumed soluble) in fact comprises two subfractions of quite different kinetic behavior (viz., the truly soluble fraction and the escaped particulate matter loss) (Dhanoa *et al*., 1999). It’s the soluble and rapidly degradable fraction and is the intercept on the Y-axis of the degradation curves.

At zero time, the DM disappearance ranged from 17.5 - 21.5% for weeds, 8.1 - 16.9% for pasture grasses and 24.6% for *L. leucocephala. C. plectostaychus* had the highest readily soluble fraction of 16.9% compared with other pasture grasses at zero time. This is a reflection of the fact that its DM component is most readily available at zero hours and it could be a good source of more nutrients for microbial growth (Djouvinov and Todorov, 1994). The pattern of DM disappearance was closely related to the NDF and ADF contents of the roughages (Table 33). *L. leucocephala*, *C. benghalensis* and *A. gangetica* had the lowest NDF content of 333.6, 403.8 and 493.4 g/kg DM (Table 33) respectively and their DM disappearance was in the same order at 0, 6, 12, 48 and 72 hours (Table 37). *P. maximum* had the highest NDF of 724.1 g/kg DM and lowest DM disappearance of 8.1% at zero time.

At all incubation periods there were no significant differences (P > 0.05) between *P. maximum* and *P. coloratum*. *P. maximum* and *P. coloratum* DM disappearance ranged from 8.1% at zero time to 39.0 and 41.7% at 72 hours respectively. At 24 hours, *P. maximum* and *P. coloratum* had mean DM disappearance of 25.9 and 25.2% respectively which was lower than 35% reported for *P. maximum* at 24 hours by Karuiki (1998). The DM disappearance of napier grass ranged from 16.6% at zero hours to 47.9% at 72 hours. At 24 hours napier grass had a DM disappearance of 30.7% which was lower than 43.6% reported by Kariuki (1998). This could be attributed to the stage of maturity of the material as the age at cutting in this study was not known. In absence of any livestock nutrition management plan and conservation measures, there was a tendency of roughages be left to overgrow and harvested only when required for feeding.

At 48 hours, the DM disappearance ranged from 47.8 - 52.7% for weeds and 34.6 - 43.1% for pasture grass species with *C. plectostaychus, P. maximum* and *P. coloratum* having less than 40% solubility (Table 37). DM disappearance above the 40% value after 48 hours of incubation is considered satisfactory (Preston, 1986). It is also generally considered to be the mean retention time of fibrous feeds in ruminants (Kimambo and Muya, 1991) and equivalent to digestibility (Ehargava and Ørskov, 1987). In addition, feed digestibility is commonly estimated after 48 hours of incubation for both *in situ* and *in vitro* methods (NRC, 2001). Thus except *C. plectostaychus, P. coloratum* and *P. maximum*, the other pasture grasses like *R. exaltata* and pasture grasses mix can contribute considerably as ruminant feed resources in the study area as their DM disappearance was above the 40% value after 48 hours of incubation.

The DM disappearance ranged from 53.2 - 57.7% for weeds and 39.4 - 50.9% for pasture grass species at 72 hours (Table 37). *L. leucocephala* had the highest value at 61.5%. Maize stover and green maize forage had a DM disappearance of 45.3 and 58.8% respectively ($P < 0.05$). This could be attributed to stage of maturity when harvested as was also reflected in their chemical composition. Maize stover had NDF and ADF of 721.7 and 438.0 g/kg DM which was higher than that of green maize forage at 676.6 and 419.0 g/kg DM (Table 33) respectively. At the end of 72 hours, over 40% of DM contents in the roughages had disappeared from the rumen with exception of *C. plectostaychus* and *P. maximum.*

The kinetics of DM degradation and effective degradability for the roughages in the study area are shown in Table 38 and Figures 5a and 5b. The DM degradation and effective degradability differed significantly ($P < 0.05$) between the roughages. The effective degradability (ED) of DM decreased with increase in outflow rates. Ikhimioya *et al*. (2005) also observed that ED of DM decreased as the outflow rates increased. The ED at outflow rates of 2, 5 and 8% were less than 50% for all roughages. The soluble fractions ranged from 17.68 - 21.95% for weeds and 8.73% - 16.54% for pasture grasses and significantly different ($P < 0.05$). *L. leucocephala* had the highest solubility of 26.07% and was significantly different ($P < 0.05$) from all the others except *C. benghalensis*. The relatively high solubility in *L. leucocephala* and *C. benghalensis* reveals their potential of being good sources of more nutrients for microbial growth (Djouvinov and Todorov, 1994). This was reflection that more of their DM was readily soluble at all incubation periods. The differences in DM disapearance between roughages are attributable to individual characteristics of each, the most important being species (Janicki and Stallings, 1988; Nocek and Grant. 1987) and maturity (Stallings *et al*., 1991; Kariuki, 1998).

Table 38: DM degradation characteristics and effective degradability of common roughages

	Degradation characteristics				Effective degradability (%)				
Roughages	**a[1] (%)**	**b[2] (%)**	**c[3] (/hour)**	**a+b[4] (%)**	**k=0.02**	**k=0.05**	**k=0.08**	**RSD**	**Lag time**
Weeds									
A. gangetica	17.68^{cd}	42.54^{bc}	0.028	60.22^{bcde}	41.10^{bc}	31.90^{bc}	27.68^{c}	2.41^{bc}	0.475^{ab}
C. benghalensis	21.95^{b}	51.04^{abc}	0.020	72.99^{abc}	45.90^{ab}	35.50^{b}	31.67^{b}	2.85^{ab}	0.000^{b}
Crop residues									
Maize stover	14.27^{def}	40.46^{bc}	0.024	54.73^{cde}	35.27^{de}	25.95^{def}	23.07^{de}	2.79^{ab}	0.033^{b}
Maize forage	18.66^{bc}	63.58^{a}	0.015	82.24^{a}	44.15^{b}	32.35^{bc}	28.05^{c}	3.77^{a}	0.000^{b}
Planted fodder									
Napier grass	16.10^{cde}	48.06^{abc}	0.023	64.16^{bcd}	37.80^{cd}	28.75^{cd}	25.16^{cd}	2.80^{ab}	1.090^{a}
Pasture grasses									
P. maximum	8.73^{g}	36.79^{bc}	0.032	45.52^{e}	30.13^{e}	22.28^{f}	18.68^{f}	2.71^{ab}	0.033^{b}
P. coloratum	10.37^{fg}	36.06^{c}	0.031	46.43^{de}	31.53^{e}	23.53^{ef}	19.95^{ef}	2.96^{ab}	0.000^{b}
C. plectostaychus	16.54^{cd}	44.22^{bc}	0.012	60.75^{bcde}	31.62^{e}	24.30^{ef}	21.78^{def}	1.32^{c}	0.867^{a}
R. exaltata	12.01^{efg}	53.79^{ab}	0.020	65.80^{abc}	37.13^{cd}	26.28^{def}	22.03^{def}	3.47^{ab}	0.000^{b}
Natural pastures	15.33^{cde}	44.62^{bc}	0.024	59.95^{bcde}	35.43^{de}	27.25^{de}	23.93^{d}	2.60^{ab}	0.000^{b}
Tropical shrub									
L. leucocephala	26.07^{a}	48.37^{abc}	0.042	74.44^{ab}	49.23^{a}	39.38^{a}	35.48^{a}	2.28^{bc}	0.000^{b}
S.D	**4.95**	**12.04**	**0.013**	**14.17**	**6.27**	**5.26**	**4.91**	**0.97**	**0.67**

[a] Means bearing different superscripts within columns are significantly different ($P < 0.05$). Superscripts 1, 2, 3, 4 constants in the equation $P = a+b(1-e^{-ct})$ where 'P' is level of degradation at time 't'; 'a' is the readily soluble fraction; 'b' is insoluble fraction but degradable in rumen; 'c' is the rate of degradation of 'b' per hour and 'a+b' is the potentially degradable fraction. ED (k=0.02; 0.05; 0.08) is effective degradability calculated with outflow rates of 2, 5 and 8%. S.D is the standard deviation.

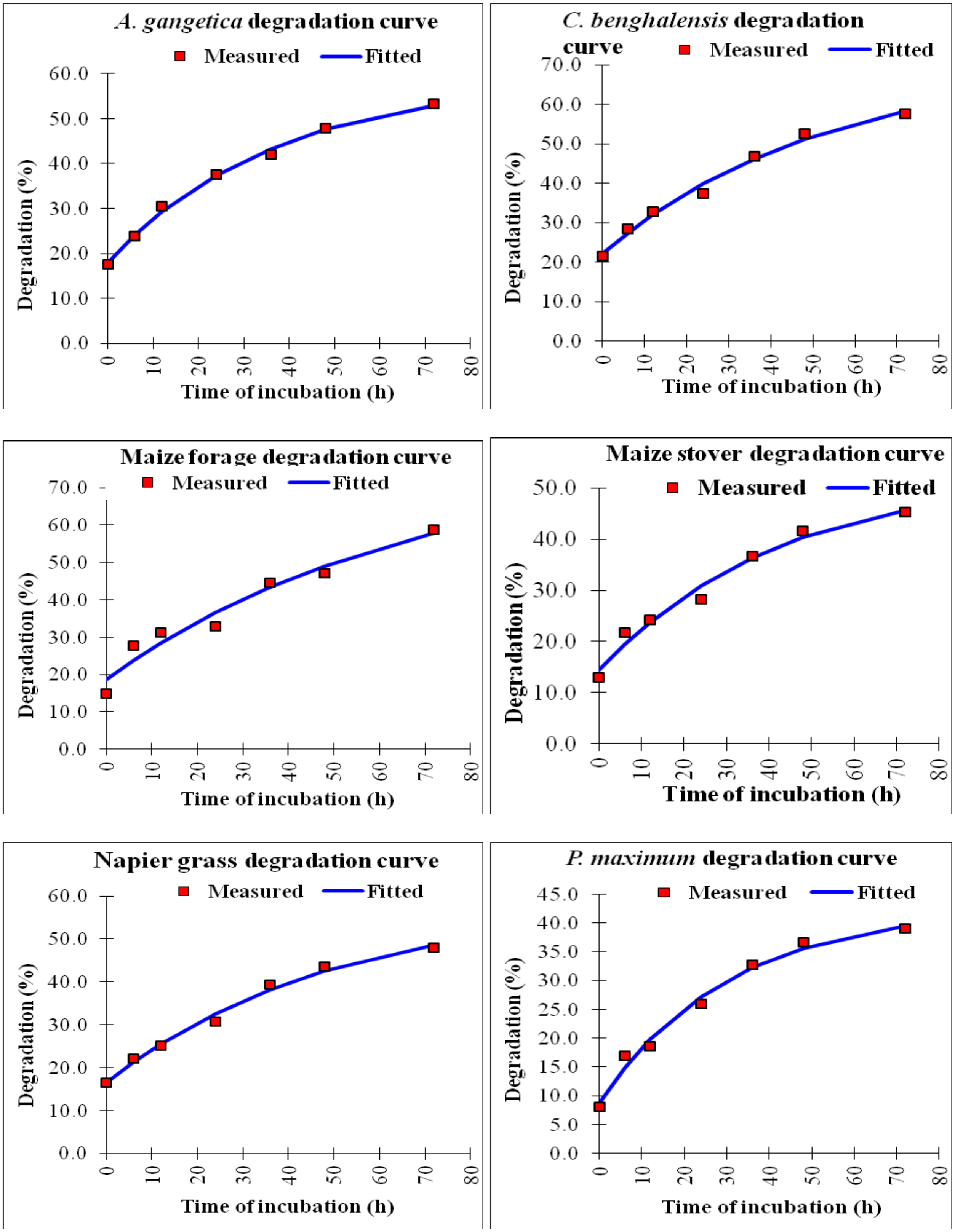

Figure 5a: Dry matter degradation curves of common roughages at outflow rate of 0.05/hour

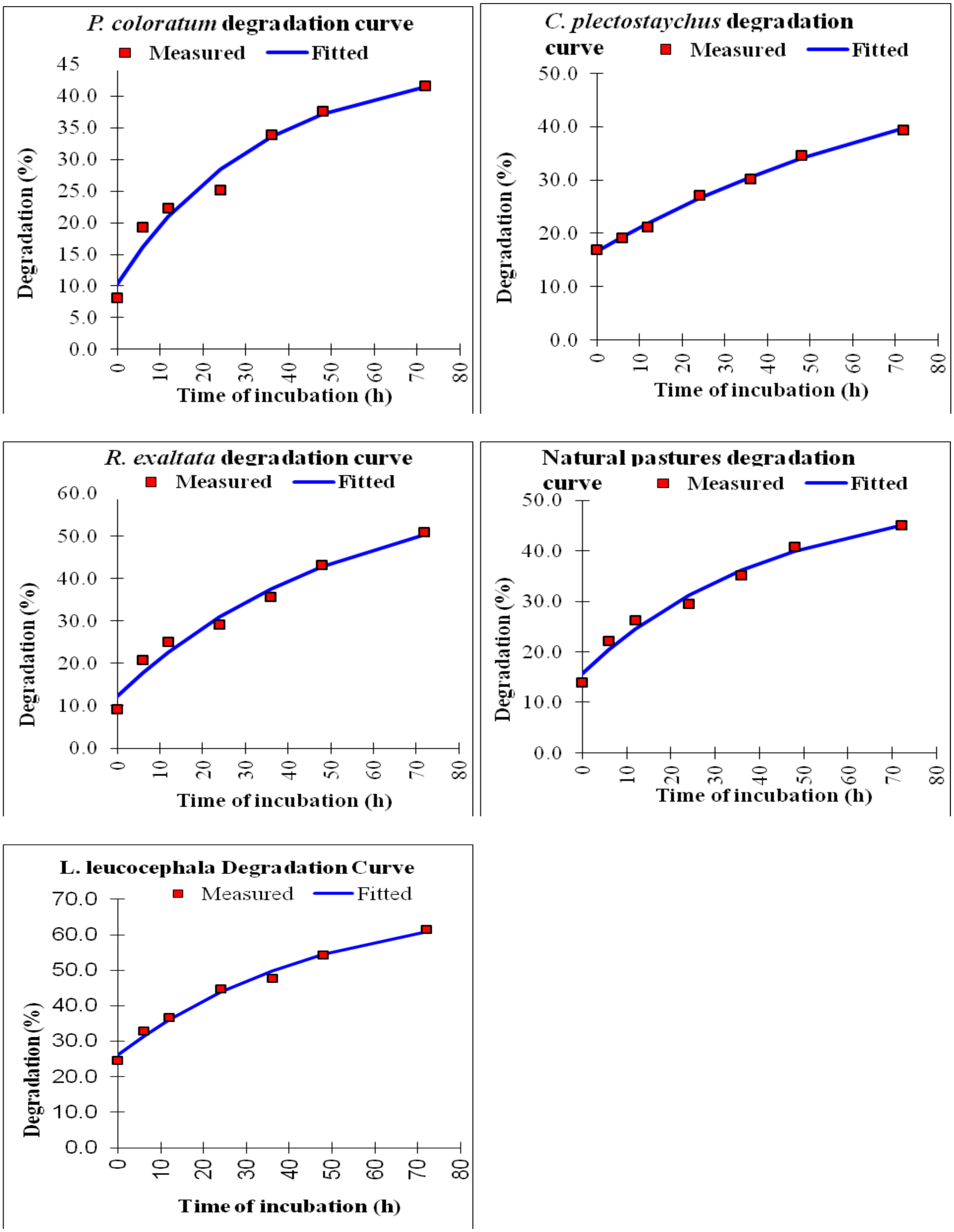

Figure 5b: Dry matter degradation curves of common roughages at outflow rate of 0.05/hour

The DM solubility for tropical pastures has been reported to be low (Kariuki, 1998; Stares and Kategile, 1992). Stares and Kategile (1992) reported DM soluble fraction of 17.0, 18.2 and 21.7% at zero hours for *Chloris gayana*, *Cenchrus ciliaris* and *P. maximum* respectively. This was higher than 8.73, 10.54 and 12.01% reported for *P. maximum, P. coloratum* and *R. exaltata* respectively in this study. Kariuki (1998) reported DM solubility of 20.5% for *P. maximum* was higher than 8.73% in this study. *C. plectostaychus* had a DM soluble fraction of 16.54% which was lower than 20.6% reported by Kariuki (1998). Napier had a solubility of 16.1% which was lower than 18.0% reported by Stares and Kategile (1992) and Kariuki (1998). In this study, the natural pastures NDF content ranged from 603.8 - 724.8 g/kg DM (Table 33) and can be classified as high which is likely to depress their digestibility and hence intake. However, adequate fibre which is total cell wall contents measured as NDF is necessary for rumination, saliva flow, rumen buffering and health of rumen wall (Fox *et al*., 1992). As observed earlier, the differences could be due to agronomic practices where most farmers did not manage for example their napier as recommended through weeding, returning slurry and applying fertilizer as well as age at cutting.

The readily soluble fraction ‘a’ represents that part which immediately disappears when feed enters the rumen (Ørskov *et al*., 1980). These losses accrue from readily soluble materials that leave the bag through the pores. In addition, washing of some soil particles attached to the materials could contribute, as part of soluble fraction of the sample (Redimio, 1998). However, these differences do not appear to affect the rumen degradation characteristics (Kyle and Hovell, 1987) but the small particles produced by grinding dried samples may result in overestimation of zero time losses (Lopez *et al*., 1995). Additionally, the ‘soluble’ fraction does not go to waste in the rumen as the small particles that leaves the nylon bag will be digested (Orskov, 1992). The negative difference between the measured and fitted values could be attributed ton presence of lag time (Chen, 1995).

The insoluble but degradable fraction 'b' in rumen differed ($P < 0.05$) between various roughages (Table 38). It varied from 42.54 - 51.04% for weeds and 36.06 - 53.79% for pasture grasses. However, the high insoluble but degradable fraction of 53.76% for *R. exaltata* did not translate into high ED in this study. This may have resulted from high cell wall contents (Van Soest, 1988) as it had NDF and ADF of 671.4 and 456.2 g/kg DM respectively (Table 33). *L. leucocephala* had an insoluble but degradable fraction of 48.37% which was similar to 48.3% reported for *Leucaena* leaf meal (Promkot *et al*., 2007). The moderate insoluble but degradable fraction of *L. leucocephala* translated into highest ED at all incubation rates. It may have resulted from low fibre as it had NDF content of 333.6 g/kg DM (Table 33) which was the lowest for all roughages investigated.

The potential degradability (a+b) of DM is the measure of the proportion of the feed DM that can be fermented in the rumen if it does not pass to the lower digestive tract before maximal degradation occurs (Ørskov *et al*., 1980). It ranged from 60.22 - 72.99% ($P > 0.05$) for weeds and 45.52 - 65.80% ($P < 0.05$) for pasture grasses with *L. leucocephala* having 74.44%. The differences in solubility and potential degradability are dependent on the cellular structure of the components being degraded (Hagerman *et al*., 1992). The high potential DM degradability for weeds and *L. leucocephala* may be related to their low NDF and ADF contents (Table 33). All roughages except *P. maximum* and *P.coloratum* had potential DM degradability higher than

50%. This is a confirmation of generally low quality ascribed to tropical pastures (Kimambo *et al*., 1994; Devendra, 1995). While DM disappearance from the roughages after 48 hours of incubation except for *C. plectostaychus, P. maximum* and *P. coloratum* were satisfactory (Preston, 1986), when viewed against potentially degradable fraction, the disappearance levels of the DM in the roughages is not likely to be complete by 72 hours. Dhanoa (1988) suggested that with low quality high fibre feed, incubation should be for longer time periods to ensure that the potentially degradable fraction is reasonably characterized. This information provides an insight into the level of rumen undegradable DM post incubation for 72 hours.

According to Preston (1986) the rate of degradation ‘c’ is an important parameter in the assessment of the fermentation of roughages in the rumen. In this study, the rate of degradation ranged from 0.020 - 0.028/ hour for weeds and 0.012 - 0.032/hour for pasture grasses. *L. leucocephala* had the highest rate for DM degradation of 0.042/hour though lower than 2.6/hour reported for browse species (Osuga, 2008). Teguia *et al*. (1999) reported that browse forages in general tend to have higher rates of degradation than grasses and crop residues. *L. leucocephala* had the highest disappearance at all incubation hour except 36 hours (Table 38). However, it had an IVDMD of 54.3% which was significantly different ($P < 0.05$) with all others except *C. benghalensis* (Table 36). The higher rate of degradation of *L. leucocephala* implies that it would be more extensively degraded in the rumen in a relatively short time than the pasture grasses, napier grass and maize stover. This leads to reduced ingesta retention time in the reticulo-rumen and in effect increase feed intake.

The ED of DM is an estimate of the proportion of DM contained in the feed that can be degraded in the rumen within the time the feed is resident in the rumen (Ørskov *et al*., 1980). There were variations between the roughages. *L. leucocephala* had highest ED of DM of 49.23% while *P. maximum* had the lowest at 30.13%. At outflow rate of 2% all the roughages studied had less than 50% ED of DM values suggested by Preston (1986) to be indicative of acceptable forage quality. This may be attributable to high fibre content of the roughages (Table 33). The high potential DM degradability of *C. plectostaychus* and *P. maximum* (> 60%) did not translate into high ED values. This may have resulted from high cell wall contents. In addition, they could have high fill values hence low intake and animal productivity (Mgheni *et al*., 2001). Efficiencies of utilisation for bulky feed materials are generally lower due to the increased heat loss by heat of fermentation and energy used for work of digestion (McDonald *et al.*, 1995).

L. leucocephala had the lowest CF of 199.7 g/kg DM and highest ED while *P. maximum* had the highest CF of 351.7 g/kg DM and lowest ED at all outflow rates. *A. gangetica*, *L. leucocephala* and *C. benghalensis* had CF of less than 300 g/kg DM and corresponding high ED of more than 30% except *A. gangetica* at 8% which had 27.7%. Ikhimioya *et al*. (2005) observed that an inverse relationship exists between ED and CF content. The high potential degradability of *R. exaltata* did not translate to a high ED at outflow rate of 2, 5 and 8%. This could be attributed to low rate of the rumen degradation of 0.02/hr and high NDF and ADF values (Table 33).

The rate of degradation is an important parameter in the assessment of the fermentation of crop residues in the rumen (Preston, 1986). It is as important as the potential degradability in determining the ED, the rumen fill and thus intake by the animal. It determines the amount of the 'b' fraction that will be released within the time span limited by the rumen retention times. The low ED of DM (< 50%) at 2, 5 and 8% of the roughages in this study, despite high potentially degradable values (45.2 - 82.24%), is most likely a result of the low rate degradation observed. This acts as a limitation of feed intake as they could have high fill values hence low intake and subsequent low animal productivity (Mgheni *et al*., 2001). Such feed are retained for long periods in the rumen despite their low nutrient value and precludes other feed from entering the stomach. However, with slowest rate of degradation 'c' per hour of the rumen degradable fraction of 0.012/hour, *C. plectostaychus* appear to be a potential source of energy for use by microorganisms in the rumen (Djouvinov and Todorov, 1994).

4.5.4.2: Crude Protein Disappearance and Degradation Characteristics

The CP disappearances at different incubation times for the roughages are shown in Table 39. There were significant variations in CP disappearance at different incubation times between roughages (P < 0.05). The CP disappearance increased with time of incubation for all roughages and its pattern of disappearance over time was, with only minor variations, similar to that of the DM. For proteins, the soluble fraction at zero time includes small water soluble molecules (NPN, free amino acids and small peptides) which are released after the feed reaches the rumen and are rapidly converted to NH_3 (NRC, 1985).

The CP disappearance at zero hours ranged from 9.91 - 17.96% for pasture grasses (P < 0.05) and 16.81 - 23.54% for weeds (P < 0.05). Maize stover had the lowest CP disappearance rates at all incubation times perhaps due to the degree of lignification. It was of low quality (72.2 g/kg DM CP) with NDF and ADF of 721.1 and 438 g/kg DM respectively (Table 33). *L. leucocephala* had the highest CP disappearance rates at all incubation times. CP disappearance could be used as an indicator of degradation and the results suggest that the protein in *L. leucocephala* was the most degradable compared to that in other roughages. This makes its CP readily available for use by rumen microbes. However, there is a need to match the release of ammonia-N from dietary protein with the release of useable energy for feed resources to be of benefit to ruminants (Salter *et al*., 1979).

Table 39: CP disappearance at different incubation times for common roughages

Roughages	**Incubation time (hours)**						
	0	**6**	**12**	**24**	**36**	**48**	**72**
Weeds							
A. gangetica	23.54^{a}	34.76^{ab}	39.16^{a}	41.34^{ab}	46.41^{abc}	50.64^{abc}	58.56^{ab}
C. benghalensis	16.81^{cd}	31.08^{b}	36.66^{a}	41.07^{ab}	49.42^{ab}	58.47^{a}	62.98^{a}
Crop residues							
Maize stover	9.56^{g}	14.78^{e}	18.81^{d}	21.31^{e}	28.10^{f}	33.49^{d}	36.32^{d}
Maize forage	13.95^{def}	25.17^{c}	29.26^{b}	34.02^{bcd}	37.46^{cdef}	40.25^{cd}	46.68^{bcd}
Planted fodder							
P. purpureum	13.42^{ef}	23.14^{cd}	27.58^{bc}	33.60^{bcd}	41.18^{bcd}	45.78^{bcd}	49.17^{bcd}
Pasture grasses							
P. maximum	11.29^{fg}	18.69^{de}	20.52^{b}	26.89^{de}	33.64^{def}	39.11^{cd}	41.20^{d}
P. coloratum	9.91^{g}	21.21^{cd}	24.58^{bcd}	27.73^{de}	$39.61b^{bcde}$	42.55^{cd}	45.76^{bcd}
C. plectostaychus	11.46^{fg}	20.01^{cde}	23.81^{bcd}	26.46^{de}	30.57^{ef}	39.39^{cd}	43.37^{cd}
R. exaltata	14.78^{cde}	23.52^{cd}	26.99^{bc}	37.34^{bc}	46.60^{abc}	49.46^{abc}	54.81^{abc}
Natural pastures	17.96^{bc}	23.37^{cd}	28.41^{b}	32.35^{cd}	35.91^{def}	41.55^{cd}	46.64^{bcd}
Tropical browse shrub							
L. leucocephala	20.99^{ab}	36.69^{a}	39.26^{a}	46.20^{a}	52.57a	55.22^{ab}	66.24^{a}
S.D	**4.06**	**5.90**	**6.39**	**7.11**	**8.07**	**8.40**	**9.45**

[a] Means with different superscripts within column are significantly different ($P < 0.05$). S.D is the standard deviation.

At 48 hours, the CP disappearance ranged from 50.64 - 58.47% for weeds and 39.11 - 49.46% for pasture grass species. *C. plectostaychus*, *P. maximum*, maize stover and green maize forage had less than 40% CP disappearance at this time (Table 39). At 72 hours, only maize stover had less than 40% disapperance at 36.32%, an indication of its inability to supply CP to the cattle. Improper storage methods in the study area led to loss in considerable amounts and nutrients due to leaf shattering. The higher CP disappearance for maize forage at 0, 6, 12 and 24 hours compared to maize stover could be attributed to stage of maturity when harvested because the quality of forage crops and digestibility of nutrients reduces with the stage of maturity. Maize stover, like other high fibre crop residues, is generally deficient in nutrient content and low in digestibility (Doyle *et al.*, 1986).

Solubility plays an important role in determining the degradability of the protein, as it determines the susceptibility of the protein to microbial proteases (Satter, 1986; Bach *et al*., 2005). The solubility of proteins is partly determined by the soluble albumins and globulins and the amount of less soluble prolamins and glutelins (Tamminga, 1979). Prolamins and glutelins are insoluble and slowly degraded, while globulins are soluble and highly degradable in the rumen (Romagnolo *et al*., 1994). Albumins and globulins have a low molecular weight and are soluble in the rumen fluid, whereas prolamins and glutelins have a higher molecular weight and contain disulphide bonds, rendering them less soluble in rumen fluid (Clark *et al*., 1987; McDonald *et al*., 2002). The prolamins and glutelins are therefore harder to access by the microbes and are more undegradable than the albumins and the globulins. Albumins and globulins have a much better amino acids composition and biological value than prolamins and glutelins, and it would be beneficial if they were not degraded so rapidly (Clark *et al*., 1987).

The CP degradation characteristics and effective degradability of commom roughages in the study area are presented in Table 40 and Figure 6a and 6b.

Table 40: CP degradation characteristics and effective degradability of common roughages

Roughages	Degradation characteristics				Effective degradability (%)				
	a^1 (%)	b^2 (%)	c^3 (/hour)	$a+b^4$ (%)	k=0.02	k=0.05	k=0.08	RSD	Lag time
Weeds									
A. gangetica	26.95[a]	38.74	0.02	65.70	47.00[ab]	38.70[a]	35.30[a]	3.26	0.00
C. benghalensis	19.73[b]	50.03	0.03	69.77	48.87[ab]	37.70[a]	32.77[ab]	4.36	0.00
Crop residues									
Maize stover	9.89[f]	37.42	0.03	47.31	27.80[e]	20.25[d]	17.20[f]	2.46	0.00
Maize forage	16.15[cd]	30.13	0.04	46.28	36.25[cde]	29.55[b]	26.20[cde]	2.77	0.00
Planted fodder									
P. purpureum	14.51[de]	39.30	0.03	53.81	38.46[cd]	29.78[bc]	27.72[bcd]	5.72	0.06
Pasture grasses									
P. maximum	11.62[ef]	38.21	0.03	49.83	32.15[de]	24.05[cd]	20.60[ef]	2.11	0.10
P. coloratum	11.64[ef]	38.75	0.03	50.39	35.25[cde]	26.50[bc]	22.50[def]	3.08	0.00
C. plectostaychus	13.61[de]	44.34	0.02	57.95	33.20[de]	24.50[cd]	21.20[def]	2.92	0.00
R. exaltata	14.65d[e]	46.93	0.03	61.58	42.27[bc]	31.97[b]	30.67[abc]	2.59	0.80
Natural pastures	18.87[bc]	46.33	0.02	65.19	37.29[cd]	29.26[bc]	26.19[cde]	2.35	0.19
Tropical shrub									
L. leucocephala	24.83[a]	45.58	0.03	70.41	51.20[a]	41.05[a]	36.60[a]	3.75	0.00
S.D	**4.70**	**12.75**	**0.01**	**14.36**	**7.14**	**5.92**	**5.79**	**2.80**	**0.45**

[a] Means bearing different superscripts within columns are significantly different ($P < 0.05$). Superscripts 1, 2, 3, 4 constants in the equation $P = a+b(1-e^{-ct})$ where 'P' is level of degradation at time 't'; 'a' is the readily soluble fraction; 'b' is insoluble fraction but degradable in rumen; 'c' is the rate of degradation of 'b' per hour and 'a+b' is the potentially degradable fraction. ED (k=0.02; 0.05; 0.08) is effective degradability calculated with outflow rates of 2, 5 and 8%. S.D is the standard deviation.

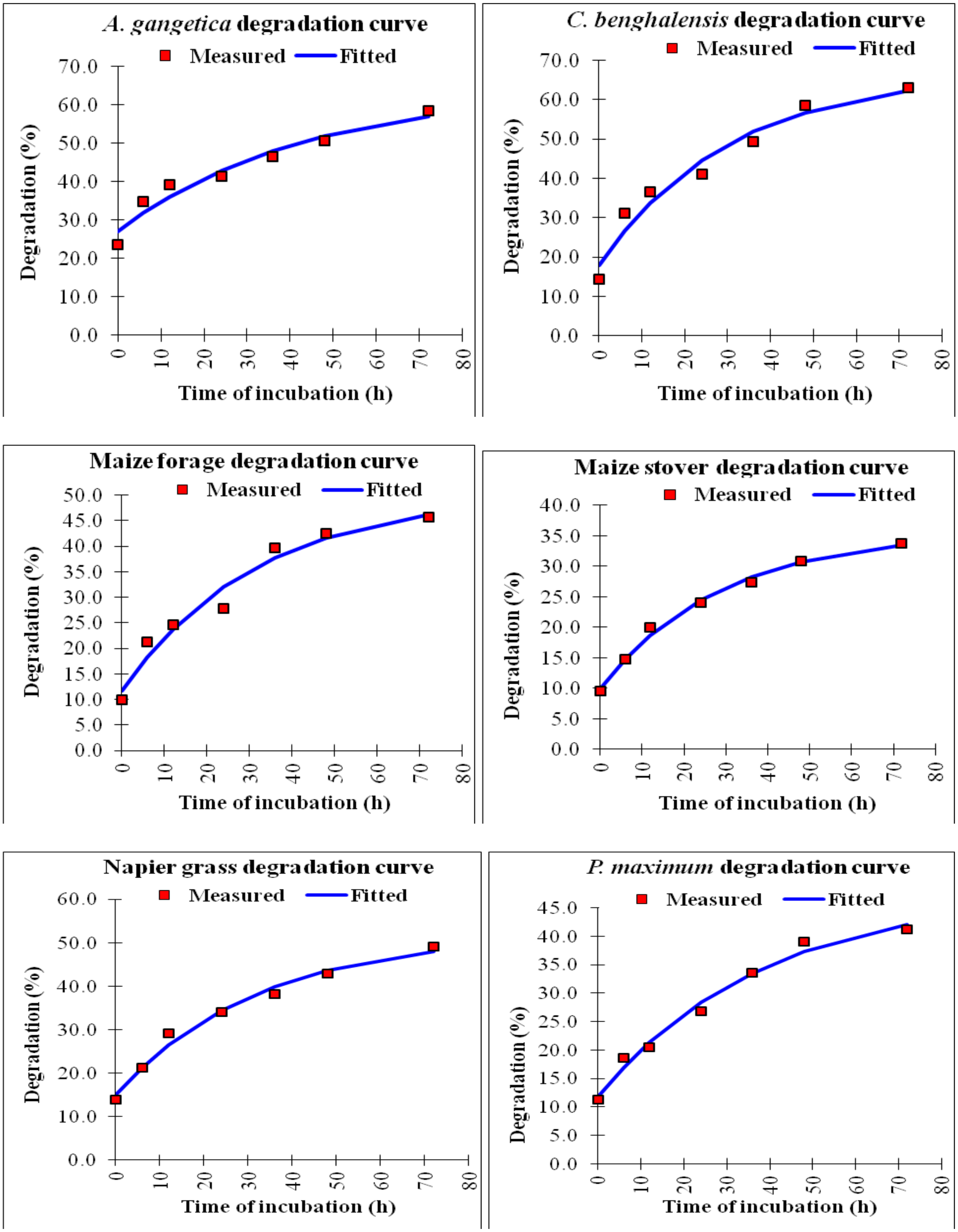

Figure 6a: CP degradation curves of common roughages at outflow rate of 0.05/hour

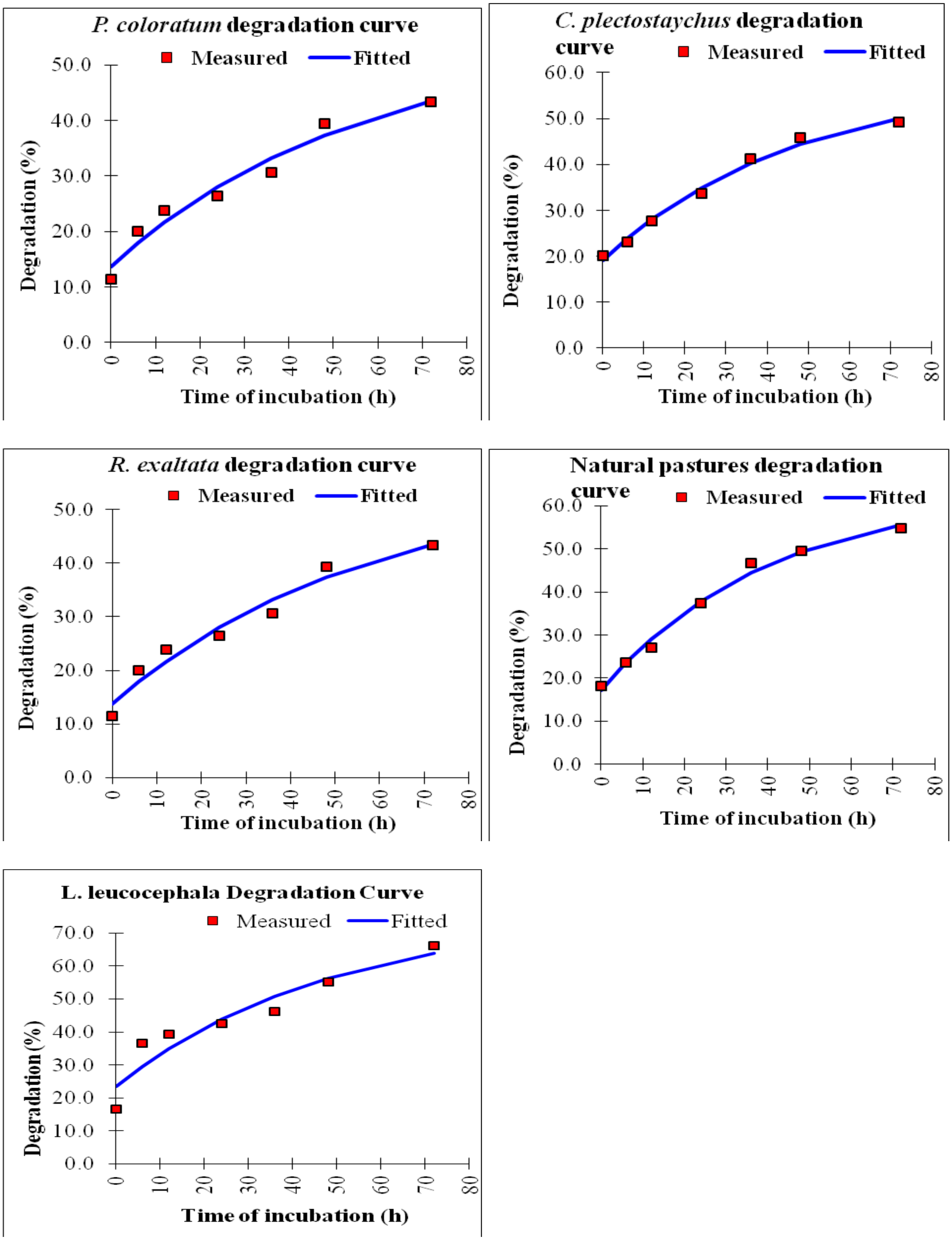

Figure 6b: CP degradation curves of common roughages at outflow rate of 0.05/hour

The readily soluble fraction 'a' and effective degradability at 2, 5 and 8% differed ($P < 0.05$) while the insoluble but degradable fraction in rumen 'b', the rate of degradation of 'b' per hour 'c', potential degradability 'a+b', RSD and lag time did not differ ($P > 0.05$) between the roughages. The most important factors affecting microbial protein degradation in the rumen include the type of protein, interactions with other nutrients, the predominant microbial population dependent on the type of ration, ruminal passage rate and ruminal pH (Bach *et al*., 2005).

Dietary protein degradation in the rumen involves attachment of bacteria to feed particles, followed by activity of cell-bound microbial proteases (Brock *et al*., 1982). The rate and extent at which protein degradation occurs will depend on proteolytic activity of the ruminal microflora and the type of protein (susceptibility and accessibility of peptide bonds). The degradability of protein in the forage for ruminants is affected by forms of protein reserves (Wallace *et al.*, 1987) where physical and chemical features of forage, which may undergo ruminal fermentation are located in the cellular walls (Tamminga, 1983; Ellis *et al*., (1988), season of the year and vegetation species, degree of lignification (Deinum, 1984) and type of conservation (Vik-Mo, 1989).

The a-value is usually accepted to give an indication of soluble protein (NRC, 2001). It's a function of both the crude protein content of the feedstuff and protein solubility. The water soluble CP fraction 'a' ranged from 19.73 - 26.95% ($P < 0.05$) for weeds and 11.62 - 18.87% for pasture grasses. *L. leucocephala* had a water soluble CP fraction of 24.83% and higher ($P < 0.05$) than other roughages except *A. gangetica*. In this study, soluble fraction for *A. gangetica* was the highest at 26.95%. The water soluble CP fractions for L. leucocephala in this study was comparable to 25.1 and 25.6% reported by Kariuki (1998) and Ndikumana and de Leeuw (1993) for the whole plant respectively but lower than 38.11% for *Leucaena* leaf meal by Promkot *et al*. (2007). *P. maximum* had water soluble CP fraction of 11.62% which was lower than 23.4 and 34.7% reported by Kariuki (1998) and Ndikumana and de Leeuw (1993) respectively. The solubility of maize stover and maize forage differed significantly ($P < 0.05$) at 9.89 and 16.15% respectively. This is in agreement with Van Soest (1982) and Van Vuuren *et al.* (1991) findings that as the plant mature the solubility of crude protein decreases due to enlargement of the cellular wall and degree of lignification (Deinum, 1984).

The 'b' fraction is important as it represents the protein that may potentially escape rumen degradation but can be absorbed in the small intestine (NRC, 1985; NRC, 2001) and contributes substantially to potential degradability 'a+b' (Ørskov *et al*., 1980). The insoluble but rumen degradable CP did not vary ($P > 0.05$) between roughages and ranged from 38.74 - 50.03% for weeds and 38.21 - 46.59% for pasture grasses. Maize stover and green maize forage had 'b' fraction of 33.74 and 47.55% respectively and were not different ($P > 0.05$). The 'b' fraction for napier was within the range of 47.4 and 48.0% for *P. purpureum* at 6 and 12 weeks of regrowth reported by Kariuki (1998). Muia (2000) reported a higher 'b' value of 67.1% for napier grass at 10 weeks (height: 1.03m) and a lower value of 42.2% for mature napier grass at 15 weeks (height: 2.0m). The differences in CP solubility could be attributed to increased lignification of nitrogen at different stages of maturity at harvesting.

Potential degradability ('a+b') is the measure of the proportion of the feed CP that can be fermented in the rumen if the feed does not pass to the lower digestive tract before maximal degradation occurs (Ørskov *et al*., 1980). The potentially degradable CP ranged from 65.7 - 69.77% for weeds and 49.83 - 65.19% for pasture grasses and was not significantly different ($P > 0.05$). Maize stover and green maize forage had potential degradable CP of 46.79 and 59.88% respectively. *L. leucocephala* had the highest potential degradable CP of 70.41% which was comparable to 75.6% (Ndikumana and de Leeuw, 1993). Napier grass and *P. maximum* potential degradable CP were lower than 85.1 and 90.8% respectively reported by Ndikumana and de Leeuw (1993). The potential degradability is inherent attributes of the NDF (NRC, 2001). There was an inverse relationship between NDF (Table 33) and potential degradability (Table 40) for *L. leucecephala, C. benghalensis, A. ganegtica,* mixed pastures and *R. exaltata.* As the NDF content increased, the potential degradability decreased and vice versa due to lower digestibility of NDF.

The rate of degradation 'c' determines the amount of the 'b' fraction that will be degraded within the time span limited by the rumen retention times. The rate of passage and, consequently, the content of rumen degradable protein (RDP) and rumen undegradable protein (RUP) in the feeds is affected by dry matter intake (NRC, 2001) and specific diet components, such as concentrate and forage (Seo *et al*., 2006). The rate of degradation ranged from 0.023 - 0.029/hour for weeds and 0.019 - 0.031% for pasture grasses. *L. leucocephala* had a mean rate of degradation of 0.029/hour which was lower than 0.079/hour for *Leucaena* leaf meal reported by Promkot *et al*. (2007). Maize stover had the highest rate of passage at 0.034/hour and lowest potential degradability of 46.79%. Natural pastures and *L. leucocephala* had the lowest rate of passage of

0.019 and 0.029/hour and highest potential degradability of 65.19 and 70.41% respectively. This was in agreement with Ørskov and McDonald (1979) that protein degradation is inversely related to the rate of passage through the rumen.

The degree to which protein will be degraded in the rumen is greatly influenced by the time that the ingested feed is retained in the rumen (Satter, 1986). Retention time also affects the microbial growth in the rumen (Russell *et al*., 1992). At lower ruminal retention times, legumes may have greater DM digestibility because of their lower NDF content (as NDF has lower digestibility) than grasses which have higher NDF (Varga *et al.,* 1990). However, Varga and Hoover (1992) reported that forage species differ in their rate of ruminal NDF degradation which is in turm affected by stage of maturity (Cherney *et al*., 1983).

This was confirmed by the high ED of DM and ED of CP for weeds and *L. leucocephala* which were considered as source of proteins as they had lowest NDF (Table 33). Variation in nutrients supply for ruminants is mostly related to forage characteristics and intake potential (Mertens, 1994) as less than 65% of the fibrous plant cell walls are efficiently digested in the total digestive tract of ruminants (Van Soest, 1994). The CP content of all forages was however higher than 7% required for optimal rumen microbial activity (McDonald *et al.,* 2002). This indicates that for all the roughages studied, the capacity to uptake these compounds by the rumen microorganisms were adequate during the first phases of the protein degradation (Juárez-Reyes, *et al*., 2004).

Effective degradability of CP refers to the amount of protein that would actually be degraded, and is therefore dependent on the time that the protein is retained in the rumen (Ørskov *et al*., 1980). The ED of CP is an estimate of the total amount of N captured and utilized by the rumen micro organisms for growth and synthesis of microbial protein (AFRC, 1993). The ED of CP decreased with increase in outflow rates. The EDCP ranged from 47.0 - 48.9% to 32.8 - 35.3% for weeds at outflow rate of 2 and 8% respectively. The ED of CP for *L. leucocephala* and *P. maximum* were highest and lowest in the entire outflow rates used in calculation respectively. The effective degradability of CP was less than 50% calculated at outflow rates of 2, 5 and 8% except for *L. leucocephala* at outflow rate of 2%. However, it has been shown that a major factor that affects N availability in the diet consumed by animal is the amount of N bound to ADF, which may constitute up to 50% (Ramirez *et al*., 1991). As the ruminal fermentation process is partially regulated by the fibrous content of the diet, the relatively low concentration of fibre components in *L. leucocephala, A. gangetica* and *C. benghalensis* can facilitate the colonization of the feed by the rumen microbial populations, which in turn might induce higher microbial activity and fermentation rates, therefore improving digestibility (Van Soest, 1994). *L. leucocephala* had lowest NDF content of 333.6 g/kg DM and highest EDCP while *P. maximum* had the highest NDF content of 724.8 g/kg DM and lowest EDCP at all outflow rates.

Protein availability has been reported to be likely to limit milk production within the coastal region (Muinga, 1992). Supplementation of low quality tropical forages with high CP sources increases both energy and protein supply leading to enhanced animal performance (Norton and Poppi, 1995). This has been demonstrated using legumes in cattle (Muinga *et al*., 1995; Abdulrazak *et al.,* 1996; Kariuki *et al*., 1999; Juma *et al*., 2006). Therefore, from nutritional point of view, the high potential degradability of *L. leucocephala, A. gangetica* and *C. benghalensis* could be an advantage when they are used as source of protein supplements as they can be grown by small-scale farmers' within the study area. This view is supported by the findings of Salter *et al*. (1979) of the need to match the release of ammonia-N from dietary protein with the release of useable energy for feed resources to be of benefit to ruminant animals.

The DM and CP degradation characteristics at 12 hours of incubation and ED (k=0.08) are presented in Table 41.

Table 41: DM and CP disappearance at 12 hours and ED (k=0.08) of common roughages

	DM characteristics		**CP characteristics**	
Roughages	**12 hours**	**ED (k=0.08)**	**12 hours**	**ED (k=0.08)**
Weeds				
A. gangetica	30.51	27.68	39.16	35.30
C. benghalensis	32.72	31.67	36.66	32.20
Crop residues				
Maize stover	24.21	23.07	22.93	20.50
Green maize forage	31.33	28.05	26.29	22.90
Planted fodder				
P. purpureum	25.16	25.16	27.58	27.50
Pasture grasses				
P. maximum	18.65	18.68	20.52	20.60
P. coloratum	22.35	19.95	24.58	22.50
C. plectostaychus	21.20	21.78	23.81	21.20
R. exaltata	25.15	22.03	26.99	28.17
Natural pastures	26.1	23.93	28.41	26.19
Tropical browse shrub				
L. leucocephala	36.68	35.48	39.26	34.15
Standard deviation	**5.54**	**4.91**	**6.39**	**5.79**

The average passage rate of high producing dairy cows is generally estimated to be 8% (NRC, 2001). If the passage rate is 8%, then the mean retention time will be 12.5 hours, as the mean retention time equals the inverse of the passage rate (Pienaar *et al*., 1989). The 12-hour value would closely resemble the mean retention time of feeds that pass from the rumen at a rate of 8% per hour. Therefore, disappearance values at 12 hours of incubation should be comparable theoretically to effective degradability values of dairy cows at 8%. There were no significant differences between DM and CP values at 12 hours of incubation and ED of DM and CP at outflow rate of 8% (P > 0.05). Except for *P. maximum* DM and CP 12-hour values, the CP 12-hour value of the others was slightly higher than the ED at 8% outflow rate. The over estimation of fermentability is mainly a problem at shorter incubation times, which representative of the short retention times (Dewhurst *et al*., 1995).

4.6: Conclusions

The chemical composition and rumen fermentation kinetics of the weeds, crop residues, napier grass, pasture grasses and tropical browse shrub presented significant variations between the feed resources studied. There were significant differences between some roughages in the DM and CP disappearance, readily soluble fraction, the rate of degradation of 'b' per hour and effective degradability calculated with outflow rates of 2, 5 and 8%. *A. gangetica*, *C. benghalensis*, *L. leucocephala* and maize forage showed better nutritional quality in terms of their IVDMD, rumen disappearance and effective degradability characteristics compared to the other roughages. They had a mean CP of over 13% and potential DM and CP degradability of above 50%. As a result they should be considered potential sources of superior roughages in Coastal Lowlands of Kenya. In particular, *C. benghalensis* could be considered potential source of roughage in this climatic zone in the dry season when regular feed resources are in short supply and low in quality. As a result, they can be used to supplement poor quality grass particularly during the dry season and as a consequence, help to reduce the high feed costs of dairy cattle in small-scale farms in Coastal Lowlands of Kenya. The results of chemical composition, DM and CP degradation kinetics could also be important when considering feed ration formulation and supplementation strategies for ruminant diets. The information could be useful in the planning of ruminant diets particularly during the dry season in the study area.

Despite their relatively poor nutritive value, maize stover and natural pastures whose quality depends on stage of maturity were the main basal feeds through out the year. However, none of the pasture grasses made it to be a good nutritional quality grass to supply nutrients to the dairy cattle production systems in the Lowlands of Kenya as sampling and harvesting of pasture grasses was not based on maturity of phenological stage. Yet if pasture is harvested at bloom-milk stage, it is of high nutritional quality and excess can also be conserved as hay. Therefore, farmers' shuold be encouraged to harvest pasture grasses at bloom-milk stage in order to take advantage of their rich nutrient supply. As a result more research and development efforts shuold be geared towards improvement of the pasture grasses species.

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5.0. DETERMINATION OF FORAGE DRY MATTER PRODUCTION AND DAIRY CATTLE REQUIREMENTS IN COASTAL LOWLANDS OF KENYA

5.1: Introduction

Farmers in Coastal Lowlands of Kenya mainly depend on rain-fed forage production for their livestock (Ramadhan *et al.*, 2008; Muinga *et al.*, 1999; Mureithi *et al*., 1998). The rainy seasons are associated with high biomass production and animals are fed on a variety of feeds, including weeds from the arable land while the planted forages are spared for the dry season (Muinga *et al.*, 1999). The reliance on rain-fed forage production leads to forage scarcity during the dry months of January to March and July to September. Low quality crop residues including maize stovers, mixed pasture grasses and dry grass from fallow land are then often the only feeds available to livestock (Lebbie *et al*., 1992).

In response to the seasonal variations in both quality and quantity of feed availability, there is an overall reduction in dairy cattle productivity characterized by low calving rate, low calf birth weight, high calf mortality, low weaning weight, reduced mature body size and more importantly low milk production (Salami *et al*., 2010). It is also noteworthy that keeping large numbers of animals beyond the carrying capacity of the land is associated with high risks of losses from death of animals during prolonged dry seasons and droughts (Winrock, 1992), a common phenomenon in the Coastal Lowlands of Kenya. Therefore, consideration of seasonal distribution and selective utilization of feeds are important factors in the assessment of cattle production systems in the area. The objective of this study was to describe the relationships between seasonal feed availability (quantity and quality), live weight change and milk production in the Coastal Lowlands of Kenya.

5.2: Materials and Methods

5.2.1: Study Area

The study was conducted in the Coastal Lowlands of Kenya (Kwale and Kilifi counties) which fall in over five agro-ecological zones characterized by different climatic, topographic, soil, and other environmental features that influence the potential of agricultural development (Jaetzold and Schmidt, 1983). The study area is described in detail in section 3.2.1.

5.2: Data Collection

5.2.1: Study Methodology

A longitudinal survey carried out from May 2012 - June 2013 using a checklist covering a purposive sample of 32 farms from the main survey sample of 415 households described in section 3.2.2. The longitudinal design methodology is detailed in section 4.3.1.

5.2.2: Animal Performance

For assessment of dairy cattle performance, 32 farms purposively selected from the main survey sample households were monitored by trained enumerators every two weeks for 12 months. Data was collected on milk production/cow/day, breed and number of cattle, age, parity number and live weight change (LWC) (Appendix 7.4). Milk production/cow/day was measured using a graduated measuring jar to the nearest 100ml. Daily milk yields were recorded by farmers while *ad hoc* enumerators' visits were used to crosscheck the validity of the data. Dairy cattle live weight changes (LWC) were estimated using a weighing tape based on heart girth measurements. Live weight change was calculated as the difference between initial and final live weights over specified intervals.

5.2.3: Feed Production

Feed production was based on purposive sample of 32 farms from the main survey sample for 12 months. Detailed specific farm forage production and utilization information was captured in order to analyze the seasonal effects of feeds on milk production and mean live weight changes. The farms were visited every two weeks by trained enumerators to collect data on feeds (quantity, quality and source i.e. on-farm or off-farm). The feed resources included purposely grown fodders/ pastures such as napier grass, legumes, crop residues, roadside grass, cereal milling by-products and Non-Conventional Feed Resources (NCFR).

For determination of forage production, 150 plots were selected in different farms at harvesting time during season I (short rains dry season from July - September 2012), season II (short rains season from October - December 2012), season III (long rains dry season from January - March 2103) and season IV (long rains season from April - June 2013). The yields for each of the standing forage were assessed from a 2m x 2m plot by hand cutting at ground level using a panga or a sickle. Forage from each plot was weighed and two samples collected in separate paper bags. The grass samples for yield determination were collected shortly before grazing. To determine the species composition of natural pastures, two diagonal transect lines were laid out in each pasture field in 25 of the 32 farms. Along each transect line; five regularly spaced 1 m^2 quadrants were thrown. In each quadrant, the relative composition of different plant species was determined, clipped and weighed. The dry matter yield per hectare was computed per type of fodder and per farm by adding the yields from each of the plots with a particular fodder. The information collected was used to depict the seasonal availability of forage across the year.

5.2.4: Forage Requirement

Quantities of forages offered to the herd were measured and recorded daily by farmers. To avoid biased observation, visits were done on an *ad hoc* basis by enumerators. Forage requirement was estimated from the estimated body weight of cattle on the farm. The information collected was used to depict the seasonal animal forage requirements across the year. Total live weight change (TLWC) for the current herd in the study area was estimated from the observed LWC per animal on the selected 32 farms multiplied by observed herd size (HS) in the 415 farms. Dairy cattle normally consume about 3% of their body weight (BW) in forage dry matter per day (McDonald *et al*., 2002). Total DM availability for each forage and crop type was estimated by subtracting 25% unavoidable grazing and/or harvesting losses in the field (Zemmelink, 1995). The standard used for one Tropical Livestock Unit is one cow with a body weight of 250 kg (Heady, 1975).

5.3: Data Analysis

5.3.1: Model Calculations

The aim of modeling was to determine the effects of seasonal feed production on cattle DM intake, live weight change (LWC) and milk production in Coastal Lowlands of Kenya. The results would show whether cattle production could be increased at the current feed supply by reducing actual herd size (HS) to the level of optimum feed use, or, alternatively, by increasing production of quality feed. In addition to quantity and quality of available feed, the productivity of an animal is affected by among other factors the genetic makeup of the animal, the physical environment and health (McDonald *et al.,* 2002), but these were not considered in this study. The calculations were performed in Microsoft Excel. The model calculations included the following parameters:

a) Intake of DM (g/TLU/day),

b) Herd size (HS), tropical livestock units (TLU) at a given level of feed use,

c) Mean live weight gain (MLWG) (g/ TLU/day),

d) Total annual live weight gain (TLWG) of the herd (kg/ year),

e) Mean milk production (MMP), (litres/TLU/day),

f) Total annual milk production (TAMP) of the herd (litres/year)

The calculations were performed for one year, comprising 12 months from July 2012 to June 2013, following two approaches (i): dividing the year into 4 equal periods of 3 months each and taking into account seasonal variations in feed availability; (ii) pooling all available feeds annually and assuming appropriate storage and carry-over between seasons where necessary. In the short dry season (July) cattle graze on natural pastures and farmers harvest part of the natural pastures for carry-over to the period August - September; these three months were defined as season I. October marks the onset of short rains and appearance of lush pastures by November - December which are fed to livestock; these three months were defined as season II. In early January crop harvesting starts and after threshing, crop residues are stored for feed from January to March; these three months were defined as season III. In the main rainy season (April - June) feed availability is a serious problem; these three months were defined as season IV. In addition, the following measurements were used in model calculations:

a. Milk production for different breeds of cattle over a period of 12 months recorded daily.

b. On-farm forage production (mt DM/year) estimated from field measurements = Forage production (mt DM/ha) x ha x number of cuts/year.

c. Herd feed requirements (mt DM/year) = Total cattle herd live weight x 0.03 x 365 days.

d. Forage production deficit (mt DM/year) = Estimated herd feed requirements (mt DM/year) - estimated forage production (mt DM/year).

e. Forage sourced off-farm (mt DM/year) = Estimated forage fed from field measurements (mt DM/year) - estimated on-farm forage production (t DM/year).

f. Feed intake deficit (mt DM/year) = Herd feed requirements (mt DM/year) - estimated forage fed from field measurements (mt DM/year).

g. Herd size (HS, TLU) that can be supported at a given proportion of feed use for 12 months was estimated by:

$$\mathbf{HS = TFDM/TADM} \quad \mathbf{(1)}$$

Where: TFDM is total available feed DM at a given proportion of feed use (t DM/year) and TADM is total annual DM intake (t DM/TLU/year).

h. Cattle live weight change (LWC) was estimated using heart girth tape twice a month. Mean live weight gain (MLWC, g/TLU/day) of the herd for 12 months was estimated by:

$$\mathbf{MLWG = (TMLW - TILW)/TLU} \quad \mathbf{(2)}$$

Where: TMLW is the total monthly live weight of the herd (kg/month), TILW is total initial live weight of the herd at the beginning of the month (kg/month) and TLU is a hypothetical animal weighing 250kg used to bring all classes of animal types under a common denominator.

5.3.2: Parameterization and Sensitivity of the Model

In the model, all cattle were expressed in TLU without distinguishing different classes and breeds. Intake of DM which can support a given HS at a given proportion of feed use for 12 months was calculated using equation 1, which in turn controls mean live weight change in equation 2 and mean milk production. To determine whether the cattle DM daily requirements were met, the field measurements were compared by assuming that cattle normally consume about 3% of their body weight (BW) in forage dry matter each day.

5.4: Results and Discussions

5.4.1: Land Use Parameters and Feed Production in Coastal Lowlands of Kenya

Land use for production of roughages and the estimated DM production in the study area are shown in Table 42.

Table 42: Land use parameters and feed production from cultivated land and natural pastures

Land use parameters	Total area (ha)	Proport -ion of area (%)	Forage production (mt DM /ha/cut)	Forage production (mt DM /year)[a]	DM feed availability (mt DM /year)[b]	Basal feed resource (%)
Cultivated land	320.2	43.6[c]				
Napier grass	93.8	29.3[d]	1.552	582.3	436.7	15.1
Other crops[g]	23.1	7.2[d]	-	-	-	-
Maize	203.3	63.5[d]	1.058	430.1	322.6	11.1
A. gangetica	49.3	24.2[e]	1.223	241.2	180.9	6.2
C. benghalensis	88.8	43.7[e]	1.335	474.0	355.5	12.3
Pasture grasses	414.5	56.4[c]				
P. maximum	28.4	6.9[f]	1.869	212.4	159.3	5.5
P. coloratum	27.2	6.6[f]	1.605	174.6	131.0	4.5
C. plectostaychus	34.9	8.4[f]	1.839	256.7	192.5	6.6
R. exaltata	17.2	4.1[f]	1.645	113.2	84.9	2.9
Natural pastures	306.8	74.0[f]	1.125	1,380.2	1,035.2	35.7
Estimated production			**13.251**	**3,864.7**	**2,898.6**	**100**

[a] Forage is harvested four times a year except maize stovers which was cut twice; [b] Takes in account harvesting and /or grazing losses of 25%; [c] Fraction of total available land for forage production; [d] Fraction of cultivated land area; [e] Fraction of area under maize; [f] Fraction of pasture land area, [g] most common crops - cassava, sweet potatoes, cow peas, Bixa and mt DM = Metric ton dry matter.

Roughages that were commonly fed to cattle were planted fodder (napier grass), crop residues (maize stover and maize forage), pasture grasses (*P. maximum*, *P. coloratum, C. plectostaychus, R. exaltata* and natural pasture grasses mixture) and weeds (*C. benghalensis* and *A. gangetica).* This concurred with findings by Maarse *et al*. (1990), Reynolds *et al*. (1993) and Mureithi *et al.* (1998) that forages fed to the cattle were predominantly composed of local grasses, crop residues, napier grass and naturally growing broad leaved weeds in coastal region. The estimated annual forage production was 3,865 mt DM/year.

Of the available land area, 56.4% was under natural pasture grasses while 43.6% was under napier grass, maize and other crops (cassava, sweet potatoes, cow peas, Bixa). The other crops contribution to the feed supply was negligible and not considered in the study. However, field observations showed that cassava leaves and parts of stalks not retained for replanting were sometimes left in the field and/or used as animal feed by some farmers. Napier grass was grown by 71.6% of the households, occupied 29.3% of cultivated land and yielded 582.3 mt DM/year of forage material (Table 42). The area under napier grass in study area was less than the recommended 0.4 ha per cow (Stotz, 1983). The overall mean of napier grass production of 1.6 mt DM/ha/cut was lower than 2.5 mt DM/ha/cut for coastal region reported by Mureithi *et al.* (1995). However, it was similar to production of 1.5 mt DM/ha/cut obtained for a cut carried out during or immediately after a low rainfall period (Njunie and Ramadhan, 2008) in the same area.The highest dry matter yield of 3.7 mt DM/ha/cut was obtained during a period of favourable rainfall conditions and where manure was used together with some inorganic fertilizer (Njunie and Ramadhan2008).

The napier grass yield of 6.4 mt DM/ha/year in this study was very low compared to that reported on-farm from different regions of the country which averaged 16 mt DM/ha/year (Wouters, 1987) with little or no fertilizer. The yields were also outside the range of 10 - 40 mt DM/ha reported by (Schreuder *et al*., 1993). This may be attributed to the fact that most farmers did not manage their napier as recommended through weeding, returning slurry and applying fertilizer to napier grass. As a result, some napier grass stools died during the dry season. This therefore made it necessary for farmers to be always sourcing for napier grass planting material for replanting. Other than soil fertility and fertilizer rates (Snijders *et al*., 1992; Wouters, 1987), the amounts of rainfall and temperature have been reported to influence yields and quality of napier grass (Anindo and Potter 1994).

Maize, a staple food crop in the region, was grown by majority (97.6%) of small-scale farmers and maize stover was the most abundant arable by-product on the farms. Maize as the staple food was given preference and occupied 63.5% of cultivated land (Table 42). Under rain-fed conditions, 430.1 mt DM/year of maize stovers were produced which translated to 1.01 mt DM/ha/cut. The by-product of the maize crop supplied about 11% of the DM available to the cattle in form of maize stover and maize forage. In the study area, it was observed that farmers made a special effort to plant several seeds per hill with the aim of thinning the extra plants for livestock feed. Maize stover is harvested after the maize cob reaches physiological maturity and is fed when available. However, field observations during the study showed that its quality deteriorated due to poor handling and storage resulting in losses from oxidation, proteolysis, leaching and also termite attacks. The practice of feeding crop by-products like maize stover also serves to increase efficiency between the livestock and crop enterprises through nutrient cycling, an important factor given the deficiency of important soil nutrients resulting from the intensive cropping based on few purchased inputs. This practice cycles important soil nutrients particularly nitrogen and phosphorus, that could otherwise only be replenished through the purchase of more expensive inorganic fertilizer

Other crops like cassava, sweet potatoes, cow peas and Bixa occupied 7.2% of agricultrural land (Table 42). In the coastal lowlands of Kenya, cassava is the second most important staple crop after maize, where 64% of the poor depend on cassava for their livelihoods (Kiura *et al*., 2008). It has potential not only as food for humans, but also as feed for livestock and as a substitute for over exploited forest covers. Large quantity of cassava leaves is often discarded at the time of harvest, as observed by Jayaprakas *et al*. (2004) and, the potential of its residues remains unexploited and underutilized.

C. benghalensis occupied 43.7% and *A. gangetica* 24.2% of maize fields and estimated to have yielded 474 and 241.2 mt DM/year of forage respectively (Table 42). Though largely considered as a weed, the *Commelinaceae* family is one of the largest and most widespread natural tropical and sub-tropical plant families on earth (Hardy *et al*., 2001) with a wide range of uses. At the onset of the dry season, it was observed that animals prefered feeding on mixtures of weeds (*Commelinaceae*, *Amaranthaceae* and others) growing naturally in the farm environment, than on low quality crop residues.

The natural pastures acreage was 74% of land under pastures (Table 42) and included area under cashew nuts, coconut, orange and mango trees and open woodland where cattle were grazed and/or at times grasses ‘cut and carried’ for stall feeding purposes. The pastures yield ranged from 1.1 mt DM/ha/cut for mixed grasses species to 1.9 mt DM/ha for *P. maximum*. Most of the natural pastures consisted of mixed grasses species and yielded 1,380 mt DM/year while *R. exaltata* occupied 4.1% of land under pastures and yielded 113 mt DM/year.

L. leucocephala was used as protein supplement by 35.6% of farmers and planted in alleys in crop land, pastures and fodder fields and along boundaries as life fences. Depending upon climate, soil type and management practices, the production levels of any fodder plants will vary greatly. Under a range of conditions, tree species of the genera *Calliandra* and *Leucaena* have often given annual yields from 5 - 15 mt/ha of edible DM when grown in block-planting arrangements. Increasing the cutting frequency from two to six cuts over a six-month period reduced *Leucaena* DM yield from 2.3 to 1.6 mt/ha (Otieno and Heineman, 1992). However, since 1992, when the *Leucaena psyllid* (*Heteropsylla cubana*) was reported in coastal lowland (Reynolds and Bimbuzi, 1993), the productivity of *Leucaena* trees was reported to have been severely reduced. *L. leucocephala* contains high levels of nutrients, including proteins and minerals (D’Mello, 1995), highly productive, growing well into the dry season (NFTA, 1987), show high levels of digestibility, improve intake and animal performance (Abdulrazak *et al*., 1996; Abdulrazak *et al*., 1997) but the major potential limitation to the use is the widespread presence of antinutritive factors (Kumar and Singh, 1994; Kumar, 2003).

The contribution of various roughages to the basal feed varied ranging from 2.9 - 35.2%. Napier grass had a contribution of 15.1% which was higher than 7.8% in two agro-ecological zones (CL3 and CL4) in Coastal Lowlands of Kenya reported by Mureithi *et al*. (1998). Intercropping of napier grass with leguminous fodder trees could boost the quantity and quality of herbage production especially during the dry season (Nyaata *et al*., 2000; Mwangi and Wambugu. 2003). *P*. *maximum* and *P. coloratum* had a combined contribution of 10% which was lower than 21.8% reported by Mureithi *et al*. (1998). *C. plectostaychus* had 6.6% contribution which was lower than 18.2% reported by Mureithi *et al*. (1998). The differences in proportional contribution of the different roughages could be attributed to the study methodologies. Mureithi *et al.* (1998) measured contribution using farmers' perceptions while this study used estimated field production measurements.

A. gangetica and *C. benghalensis*, major weeds in the maize fields and at times in the pasture lands, contributed 6.2 and 12.3 % of basal feed respectively (Table 42). The *C. benghalensis* contribution was lower than the average of 15.4% reported by Mureithi *et al.* (1998) for two agro-ecological zones (CL3 and CL4) in Coastal region. These weeds in croplands rather than always being viewed as a problem could constitute a valuable feed resource for livestock. Weeds are collected during land preparation and after first weeding for stall-fed animals (Getz and Onim, 1993). Later in the cropping season, other weeds may be harvested or left to provide fodder for grazing animals after the crop and crop residues have been harvested. This implies that such weeds growing naturally at farm level can and are indeed being used by farmers to supplement conventional feed resources both during the wet and dry seasons.

5.4.2: Seasonal Forage Distribution in Coastal Lowlands of Kenya

The distribution of the common roughages in the study area during the 12 months varied across seasons as shown in Table 43. Majority of small-scale farmers relied mostly on tropical grasses and crop residues during wet and dry season to meet the nutrient needs of their livestock. The main planted forages were napier, grass and *L. leucocephala*. *A. gangetica* and *C. banghlensis*, weeds in the maize fields, were abundant during long rains (season IV) and short rains seasons (season II). Perhaps due to its prolific growth habits and abundance, *C. benghalensis* was also available during the short rains dry season (season I). *P. maximum* was abundant during seasons IV and II while *P. coloratum*, *C. plectostaychus* and *L. leucocephala* were abundant during seasons IV and I.

Table 43: Seasonal distribution of common roughages types

Roughages	Season I	Season II	Season III	Season IV
Weeds				
Asystacia gangetica	x	ν	x	ν
Commelina benghalensis	ν	ν	x	ν
Crop residues				
Dry maize stover	ν	x	ν	x
Maize stover	x	ν	x	ν
Planted fodder				
Napier grass	ν	ν	ν	ν
Pasture grasses				
Panicum maximum	x	ν	x	ν
Panicum coloratum	ν	x	ν	x
Cynodon plectostaychus	ν	x	ν	x
Rottboelia exaltata	ν	x	x	ν
Natural pastures	ν	ν	ν	ν
Tropical shrub				
L. leucocephala	x	ν	x	ν

Season I: July - September (2012); Season II: October - December (2012); Season III: January - March (2013) and Season IV: April - June (2013); ν indicates seasons of forage abundance and x indicates seasons of low abundance or not available.

Maize stover was abundant during seasons I and III while green maize forage were abundant during seasons II and IV but with a spillover in season I (Table 43). Napier grass and natural pastures were available throughout the year while *R. exaltata* was abundant during the season IV with a spillover in season I. Various forms of maize stover storage were observed on the farms including stacking outside around ornamental or fruit trees and under cover within the zero-grazing units leading to considerable losses in amounts and nutrients due to weathering and leaf shattering. Improper management and storage methods drastically reduce the proportions of maize stover available as feed as well as the efficiency of utilization (Promma *et al.*, 1994). Therefore, practical options for improving maize stover contribution to livestock productivity should be explored and exploited primarily based on when to harvest from fields and proper storage.

The roughage yields varied across seasons of the year as shown in Table 44 and Figure 7.

Table 44: Estimated seasonal yields (mt DM/ season) of common roughages

Roughages	**Season I**	**Season II**	**Season III**	**Season IV**
Napier grass	145.6	69.9	46.6	320.3
Maize stover/ Maize forage	43.0	193.5	86.0	107.5
A. gangetica	84.4	24.1	-	132.7
C. benghalensis	118.5	71.1	-	284.4
P. maximum	74.3	21.2	21.2	95.6
P. coloratum	43.7	26.2	24.4	80.3
C. plectostaychus	56.5	28.2	30.8	141.2
R. exaltata	35.1	13.6	5.7	58.9
Natural pastures	303.7	207.0	386.5	483.1
Estimated production	**904.7**	**654.9**	**601.2**	**1,703.9**

Season I: July - September (2012); Season II: October - December (2012); Season III: January - March (2013) and Season IV: April - June (2013) and DM is dry matter.

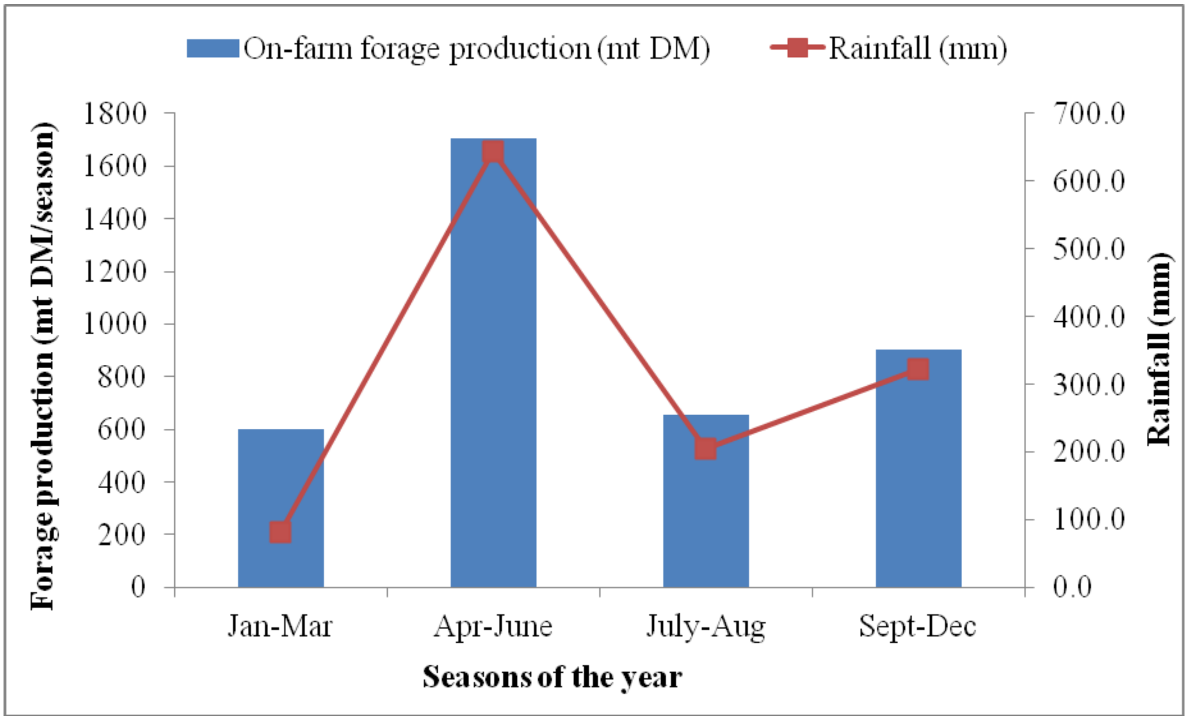

Figure 7: Effects of seasonal rainfall variability on on-farm forage production

As expected, seasonal on-farm forage production followed the rainfall patterns of the area with most forages being available during the long rains season from April to June. It was during this time when a few farmers conserved excess forage as silage. The DM yields ranged from 601.2 mt DM in season III to 1,703.9 mt DM in season IV. Therefore, small-scale dairy dairy farmers faced a feed resource constraint which worsened with frequent droughts associated with the changing climate. This change leads to reduction in herbage growth rate, quality, species composition and DM yield which is associated with reduced nutrient available to the animals and ultimately leads to a reduction in their milk productivity. In the wet seasons, the bulk of the feed consisted of fodder crops, natural pastures and weeds which were supplemented by crop residues in the dry seasons. Due to spillover from the long rains season IV, there was more DM output during season 1 despite being the short dry season than season II which was the short rains season. This was exemplified by availability of maize stovers during this season.

High availability of natural pastures was a challenge to silage making as it made farmers find silage making unnecessary. Natural pastures were conserved as standing hay. Also, due to low livestock population in the county, farms with natural pastures offered fodder that was harvested during dry spell. This was common in Kwale County where farmers living near valleys and rivers had steady supply. Farmers experienced the most acute feed shortages in season III when they had difficulties satisfying the DM requirements of their animals. During this season, farmers practicing zero-grazing or semi zero-grazing systems had to walk for long distances in search of fodder. Similarly, farmers practicing semi zero-grazing and free range grazing system had to walk long distances in search of pastures.

Crop residues like maize stover, mango leaves and roughages like mixed pasture grasses, dry grass from fallow land were available for livestock feeding but their contribution to milk production is negligible due to low protein content and digestibility. Maize stover was the main roughage produced on-farm during season II (October – December) constituting about 65.3% of feed resource and the bulk of it was utilized in season III (January – March). Utilization of maize stover, which was the main roughage during the dry season, in agreement with Said and Wanyoike (1987), was constrained by the low crude protein concentration (Nicholson 1984; Little and Said 1987).

Pastures grasses were the most important feed resource and contributed 57, 45, 78 and 50% in seasons I, II, III and VI of feed resource respectively. This is in agreement with Mureithi *et al*. (1998) who reported that natural pastures contributed 60% during the wet season and 75% during the wet season in two agro-ecological zones (CL3 and CL4) in Coastal Lowlands of Kenya.).

Utilization of pasture grasses throughout the year was however constrained the low crude protein concentration (Table 33) and low DM degradation (Tables 37 and 38) and CP degradation (Tables 39 and 40).

5.4.3: Effects of Seasonal Feed Production on Livestock Productivity in Coastal Lowlands of Kenya

5.4.3.1: Performance of Dairy Cattle

The average milk production and contribution to the total milk output from various cattle breeds in the study area is shown in Table 45.

Table 45: Average milk production and contribution to milk output for various breed

Breeds	Average milk production (litre/cow/day)	Contribution to total milk output (%)	Milk yield (litre/cow/year)
Friesian	7.3	53	2,631
Aryshire	6.7	32	2,436
Guernsey	5.6	7	1,858
Brown Swiss	7.2	5	2,596
Cross breeds*	2.3	1	833
Jersey	2.4	2	894
Mean	**5.3**	**-**	**1,875**

Crossbreeds between grade cattle with indigenous breeds.

Friesians had highest milk yields followed by Brown Swiss, Aryshire, Guernsey, Jerseys and cross breeds. The average milk yield/cow/day was 5.3 litres with a range of 2.3 - 7.3 for crossbreeds and Friesian respectively. The difference between mean milk yield/cow/day during cross-sectional survey of 5.7 litres and longitudinal survey of 5.3 litres could be attributed to stages of lactation which evened out during the longitudinal survey. Despite previous efforts from the NDDP (NDDP, 1992a; NDDP, 1994) and other development agencies like Heifer International Kenya (Mwatsuma, 2013), the study area had over the years continued to register low growth in milk production. These programs advocated for intensive dairy cattle production systems. The exotic breeds' milk production per cow per day ranged from 2.4 to 7.3 litres for Jerseys and Friesians respectively. This was lower than 8 litres recommended by Mukolwe *et al*. (1990) for cows under zero-grazing to be economical.

The estimated annual milk yield per cow ranged from 833 - 2,631 litres from the longitudinal study. Crossbreeds and Jersey had an annual milk production per cow of 833 and 894 litres respectively while Guernseys had 1,858 litres. Hence, while Jersey and Grade local crossbreeds constituted about 21.1% and 25.2% of the cattle numbers these contributed only 2 and 1% of total milk production respectively. Milk production from small-scale dairy cows in the Coastal Lowlands of Kenya was comparable to that from similar production systems in Western Kenya (Wanjala and Njehia, 2014). Bebe *et al*. (2003) quantified the breed preference for high milk production as 78%, 59%, 47% and 22% for Friesian, Ayrshire, Guernsey, and Jersey and the indigenous breeds, respectively.

In this study, the major constraint to increased milk production was identified to be nutrition. This was demonstrated by low average milk production per day which ranged from 2.3 litres for crossbreeds to 7.3 litres (Table 45) which could be attributed to inadequate nutrition characterized by low quantity and quality of feeds (Tables 33, 37 and 39). In Kenya, several studies have reported that feeding napier grass alone without supplementation yielded about 5 litres/cow/day (Waithaka *et al*., 2002; Muraguri *et al*., 2004). It has been shown through experimentation that milk yields improve when dairy cows are supplemented with feed resources having high energy and protein contents (Anindo and Potter, 1986; Muinga *et al*., 1995, Muia, 2000). Muinga *et al*. (1995) demonstrated that supplementing *Bos indicus* and *Bos taurus* cows fed napier grass *ad libitum* (CP 64 g/kg DM) with varying levels of *Leucaena* improved milk production by 28%. Jersey dairy cows when supplemented with velvet bean and lablab had milk yields of 6.3 and 6.8 kg/day respectively (Muinga *et al.,* 2002). Cows fed *Clitoria*, *Gliricidia* and *Mucuna* yielded 15, 20 and 15% more milk than those fed maize stover alone (Juma *et al*., 2006). Romney *et al*. (2000) indicated an increase in daily milk yield of 2.2 litres for every extra kilo of concentrate offered. This was an indication that supplementary feeding of lactating cows with commercial feed concentrates was a rational management practice as it led to a significantly higher mean daily milk yield.

The age of cows, age at first calving, calving interval and parity number in the study area is shown in Table 46.

Table 46: Age of cows, age at first calving, calving interval and parity number

Parameters	County mean		Overall sample			
	Kwale	Kilifi	Mean	S.D	Minimum	Maximum
Age of cows (years)	4.6	4.4	4.5	3.17	0.1	20.0
Lactation period (days)[a]	353.0	385.2	376.6	81.11	165	499
Age at first calving (years)[a]	2.9	3.1	3.1	0.52	2.0	6.0
Calving interval (days)[a]	495.7	544.6	531.5	140.50	365	973
Parity number	3.0	3.2	3.2	1.50	1	9

[a] Age at first calving (years), Calving interval (days) and Lactation period (days) significant ($P < 0.05$) between counties

The mean age of female cows in the study area was 3.5 years with 3.2 parities. The age and parity number showed that cows kept were on average young as farmer intensified their dairying. It was observed that the calving interval was longer than one year. Hence, some of the cows were still being milked after 12 months when milk production was 1 litre/day (Table 23). ATPS

(2013) reported that the production environment has both direct and indirect climate effects on dairy breed genotypes. This will adversely impact on their performance and therefore limit their potential for providing food, nutrition, income and job securities to the Kenyans (Muriuki *et al*., 2004). The direct effects on dairy include impacts on animal health, welfare, growth and reproduction, while the indirect effects are due to the impact of climate change on the productivity of pastures and forage crops.

The distribution of lactation period, age at first calving, calving interval and parity number is shown in Table 47.

Table 47: Lactation period, age at first calving, calving interval and parity number

Parameters distribution (%)	% of animals		
	Kwale county	Kilifi county	Overall sample
Lactation period (%)			
165-256 days	31.1	18.9	22.1
257-347 days	18.4	13.5	14.8
348-439 days	41.7	51.6	49.0
> 439 days	8.7	16.0	14.1
Age at first calving (years)			
2-2.5 years	29.4	9.9	14.9
2.6-3.5 years	55.6	75.5	70.4
> 3.5 years	15.0	14.6	14.7
Calving interval (days)			
305-365 days	19.4	14.9	16.1
366-547 days	42.7	27.8	31.8
548-630 days	24.3	33.5	31.0
> 630 days	13.6	23.8	21.1
Parity number			
1-2 times	72.5	66.7	68.2
3-4 times	18.3	21.6	20.8
5-6 times	4.6	10.8	9.2
> 6 times	4.6	0.9	1.8

The mean lactation period was high at 376.6 days (Table 46) with a range of 165-499 days with majority of animals (49.0%) having 348-439 days. Some of the animals (22.1%) had a lactation period of 165-256 days, an indication that some cows were drying up too early before the desired normal lactation period of 305 days (Chamberlain and Wilkinson, 2002). The mean calving interval was 531.5 days with a range of 365-973 days with majority of animals (31.8% and 31%) having an interval of 366-547 and 548-630 days respectively. The mean age at first calving was 3.1 years with range of 2-6 years and a majority of animals (70.4%) calved at 2.6-3.5 years. The prolonged calving intervals due to prolonged lactation period result in reproductive wastage in small-scale farms (Bebe *et al*., 2003b). This necessitates the need for a good breeding and feeding programme in order to ensure the average milk production was not made even lower by long calving intervals. In addition, proper detection of estrus, access to veterinary services, timely delivery of artificial insemination and on-farm feed formulation practices could alleviate the problem.

The pairwise comparisons of mean milk yields of different breeds in the study area are shown in Table 48.

Table 48: Pairwise comparisons of mean milk yields of different breeds

Breed (I)	Breed (J)	Mean Difference (I-J)	Std. Error	Sig.
Friesian	Aryshire	0.826	0.651	0.205
	Brown Swiss	1.376	1.190	0.248
	Cross breeds	1.935*	0.664	0.004
	Jersey	1.857*	0.664	0.005

. The mean difference is significant at the P < 0.05 level.

The mean yield between Friesians was significantly different (P < 0.05) with Jerseys and cross breeds. These suggested that besides poor feed quality (Table 33) and long calving interval (Table 46), the low performance of dairy herds in small-scale farms may be associated with the type of breed kept in the region.

The mean monthly milk production over 12 month's period for various cattle breeds varied as shown in Figure 8.

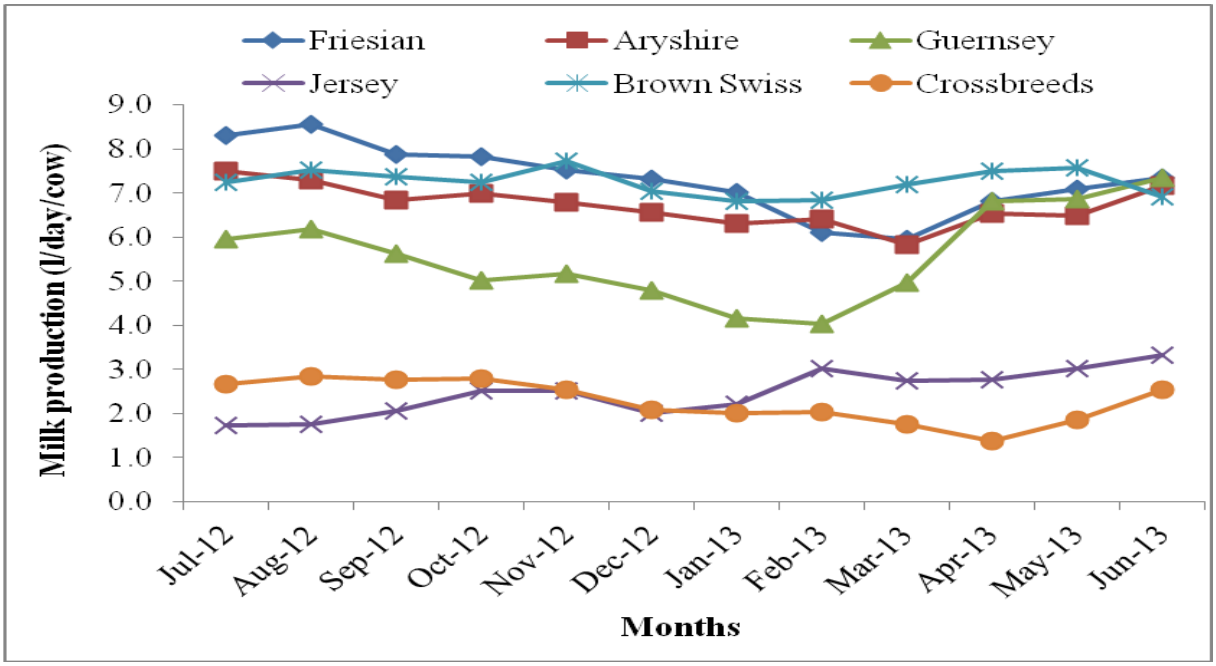

Figure 8: Monthly milk production for various cattle breeds over 12 months period

The breeds exhibited a similar pattern with a gradual reduction from August to January/February then an increase to June with the exception of Brown Swiss and Jerseys. For Jersey, there was gradual increase from July – November with a drop in December followed by rise in January/February. For Brown Swiss, milk production was relatively constant throughout the year. Jerseys appeared to be more resilient in terms of capacity to produce milk in the drier months as its milk production rose during the drier months, an indication of its ability to utilize low quality forages more efficiently. In addition, the effects of fodder growth during the long rains season and short rains seasons were felt during the subsequent short rains dry season and short rains season for Jersey and crossbreeds. This showed that milk production was breed- and season- dependent as reported by (Nobrega and Langoni, 2011**)**. To improve the quantity of milk produced on coastal lowlands, there is a need to diversify feed resources especially the utilization of crop residues (maize stover), browse legumes (*Clitoria* and *Mucuna*) and browse tree legumes *(Gliricidia sepium and L. leucocephala*), industrial by-products (molasses, wheat bran, maize bran and maize germ) and concentrates (dairy meal) amongst other common resources.

The mean daily cereal milling by-products allocation for milking cows is shown in Table 49.

Table 49: Mean daily cereal milling by-products allocation for milking cows

Cereal milling by-products	kg, as-fed/ year	Dry Matter content (g/kg)	Kg DM/year	g DM/cow/day
Maize germ	208,475	909.2	189,546	1,044
Maize bran	228,451	908.8	207,616	1,144
Wheat bran	31,613	909.6	28,755	158.5

The amount of concentrates that is often fed does not usually result in increased milk yield because only limited quantities (about 1 kg/day throughout lactation) were fed. The concentrate was usually fed during milking to supplement the roughage which mainly consisted of crop residues and natural pastures of low nutritive value. The amounts offered appeared to be unrelated to the level of production of the individual cow and varied little with the stage of the lactation. In addition, some cows did not receive any concentrate and others more than they deserved based on their milk production. This was in agreement with Wambugu (2000), Romney *et al*. (1998) and Staal *et al*. (1998) that farmers compensated for some of the forage shortages by purchasing concentrate feeds. However evidence indicates that the large majority of farmers feed a low, flat rate of concentrate throughout lactation, typical quantities being about 1 kg/day (Abate and Abate (1991).

Concentrates contributed to meeting maintenance requirements due to inadequate dry matter intake and low digestibility of forage. This was in agreement with Abate and Abate (1991) findings that the effectiveness of concentrates in promoting milk production under intensive feeding is doubtful due to small quantities fed in Kenya, an average of 0.8 kg/day to lactating cows. Farmers seem to purchase small quantities of concentrates just to complement roughage and own produced feeds rather than for supplementation. Bakrie *et al*. (1996) and Kavoi *et al*. (2010) reported that supplementary feeding of tropical ruminants must then be seen as a least-cost system which is integrated into the management of an enterprise with low stocking rates tolerating some annual weight loss and expecting a relatively low reproduction rate and annual weight gain. The low level of utilization of concentrates emphasized the importance of providing a basal diet of high nutritional quality.

Muraguri *et al*. (2004) reported mean annual milk off-take from supplemented cows of 2,195 kg which was 18.6% more than off-take from non-supplemented cows, underlying the importance of supplementation. As a result, to improve animals' performance, other cheap and preferably home grown protein supplementary feeds like fodder legumes and browse tree species are needed for cattle feeding. Inclusion of legumes in the diets could improve the nutrition of the cow (Muinga *et al*., 1992; Posler *et al*., 1993; Abdulrazak *et al*., 1996; Juma *et al*., 2006) and also play an important role of enhancing soil fertility through nitrogen fixation (Leng, 1997). However, farmers find it easier to substitute protein feeds that are of high quality with roughage feeds and own produced feed, which are of poor quality (Kavoi *et al*., 2010).

5.4.3.2: Pooled and Carry-over Feeds

Carry-over feeds refer to collecting and temporary storing of feeds to allow synchronization of feed supply to animals' feed demand for an optimum feeding regime (Assefa *et al*., 2007). It is implicitly assumed that the feeds are properly stored to maintain their quality throughout the feeding period and that labour availability is sufficient to collect, store and chop mixture of feeds for livestock. The amount of feed required depends on the weight, physiological stage of growth, lactation stage and number of cattle.

The seasonal variations in roughage production and utilization are shown in Table 50.

Table 50: Estimated seasonal variations in roughage DM yields and utilization

Parameters	Season I	Season II	Season III	Season IV	Total
Estimated on-farm forage production (mt DM) (a)[1]	654.9	904.7	601.2	1,703.9	3,864.7
Estimated amount sourced off-farm (mt DM) (b)[1]	579.8	341.9	517.3	114.6	1,553.6
Total feed available (mt DM) (a+b)[1]	1,234.7	1,246.6	1,118.5	1,818.5	5,418.3
Estimated amount of forage fed (mt DM) (c)[1]	1,216.6	1,183.9	1,109.5	1,301.6	4,811.6
Estimated cattle forage requirement (mt DM) (d)[2]	1,261.2	1,261.2	1,233.8	1,247.5	5,003.8
On-farm production feed deficit/surplus (mt DM) (a-c)	-561.7	-311.9	-508.3	402.3	-946.9
Farm feed surplus (mt DM) [(a+b)-c]	18.1	30.0	9.0	516.9	606.7
Potential feed deficit/surplus (mt DM) [(a+b)-d]	-26.5	-14.6	-115.3	571.0	414.5
Actual feeding deficit/surplus (mt DM) (c-d)	-44.7	-44.7	-124.3	54.1	-192.3

[1] Estimated from field measurements; [2]Estimated cattle forage requirement was estimated by adding 25% for feed refused, storage losses and/or harvesting losses in the field (Zemmelink, 1995); Negative value indicates a deficit.

The estimated on-farm feed production ranged from 601.2 - 1,703.9 mt DM/season (3,864.7 mt DM/year) against estimated cattle requirement of 1,233.8 - 1,261.2 mt DM/season (5,003.8 mt DM/year). This showed that the amount produced on-farm was inadequate to meet the cattle DM requirements. As a result, 1,553.6 mt DM of feed resources was sourced off-farm with the lowest and highest amounts of 114.6 and 579.8 mt DM in seasons IV and I respectively. The deficit ranged from 311.9 - 561.7 mt DM/season based on estimated cattle feed requirements and on-farm production. On-farm forage production did not meet the herd requirements except in season IV where there was a surplus of 402.3 mt DM (23.6%). This represents the amount of feed that can be conserved in season IV and used for feeding in other seasons and thus reducing the deficit. With proper management practices, through carry-over of feed resources between seasons, the overall deficit reduced from 1,381.8 mt DM (27.6%) to 979.6 mt DM (9.6%).

The total (on-farm and off-farm) available feed ranged from 1,118.5 - 1,818.5 mt DM (5,418.3 mt DM/year) in season I - IV against potential cattle requirement (d) of 1,233.8 - 1,261.2 mt DM (5,003.8 mt DM/year) (Table 50). This showed that farmers produced on-farm and sourced off-farm adequate feed to satisfy their cattle minimum DM requirements. However, the amount fed (c) was much less than this and ranged from 1,109.5 – 1,301.6 mt DM (4,811.6 mt DM/year). While the actual feeding levels had a deficit (192.3 mt DM), there was a surplus at current feeding levels of 606.7 mt DM. This was an indication that not all feed produced was fed and a substantial amount got spoilt and hence went to waste. At optimum feeding, it was only in season IV that there was surplus above animal requirements of 54.1 mt DM with season III recording the highest deficit of 124.3 mt DM. Season III coincided with the driest months of the year and hence the high deficit. Therefore, some of feed produced on-farm or sourced off-farm went to waste as field observations indicated that farmers utilized roughages without considering the use of any existing storage technologies.

The pooled seasonal feed resources indicated that the small-scale dairy cattle farmers produced about 77% of the total feed required from within their farms (Table 50). This is in agreement with estimates based on farm size, land allocation and ecological potential that most small-scale farmers in Kenya produce at best 70% of the total feed required from within their farms (NDDP, 1992a). However, their ability to sustain this production is season dependent and is compounded by now frequent adverse weather conditions and attempts to bridge the deficit through feed imports from other farms either through purchase or grazing is necessary. Farmers sourced 28.5% (1,543.6 mt DM) off-farm. However, some of the feed sourced either on-farm or off-farm went to waste (606.7 mt DM/year). The situation is further exacerbated by lack of preparedness of the farmers as exemplified by low number engaged in fodder conservation in the study area. In addition, lack of effort to conserve could be explained by farm gate price of milk not being commensurate with the conservation costs.

Acute shortages were experienced during the months of January to March ((Table 13). At this time farmers had difficulties in meeting gthe dairy cattle dry matter requirements even after sourcing off-farm. Not all farmers were self-sufficient in feed supply as 12% of the respondents' reported incidences of feed shortage (Table 13). Fodder conservation was not a common practice in this area as only about 13% reported ever conserving (Table 14). Of those who had ever conserved, 14.5% had conserved as hay and 8.2% as silage. The on-farm feed production deficit of 44.7, 77.3 and 124.3 mt DM in seasons I, II and III was bridged by sourcing off-farm. Of the farmers who occasionally had excess fodder (that amounted to 574.1 mt DM); it was either left in the fields until the need arose or sold it to their neighbours. Others used excess feed for compost making, mulching and bedding for cattle. As observed earlier, maize stover was left in open fields, under trees and in unroofed barns where its quality deteriorated.

In the absence of carry-over between seasons, there was excess fodder supply in season IV (54.1 mt DM) which reduced the amount of forage available for conservation. However, assuming appropriate carry over between seasons where excess forage is conserved based on total feed available and cattle requirements [(a+b)-d], the forage produced on-farm and sourced off-farm would be adequate to meet the requirements throughout the year and leave a surplus of 414.5 mt DM/year. The amount of feed sourced off-farm would be reduced by 27.6% from 1,573.6 to 1,139.1 mt DM/year. As such, farmers should be encouraged to conserve any surplus feed at their disposal for use during times of deficit. As a coping strategy, 16.3% (Table 15) and 14.7% (Table 16) of the farmers interviewed indicated purchase of forages as an important short and long term strategy to cope with feed shortages in order to increase milk production.

The highest amount was sourced in season II (579.8 mt DM) while the lowest in season 1V (114.6 mt DM) to bridge deficit. The rainy seasons are associated with high biomass production and animals are fed on a variety of feeds, including weeds from the arable land while the planted forages are spared for the dry season. The dry seasons are associated with low biomass production which leads to forage scarcity during the dry months (January to March and July to September). Therefore, the inability of farmers to feed animals adequately throughout the year remains the main constraint for increasing milk production in this region.

The relationship between DM availability and milk production and MLWC over the seasons varied as shown in Figures 9a and 9b.

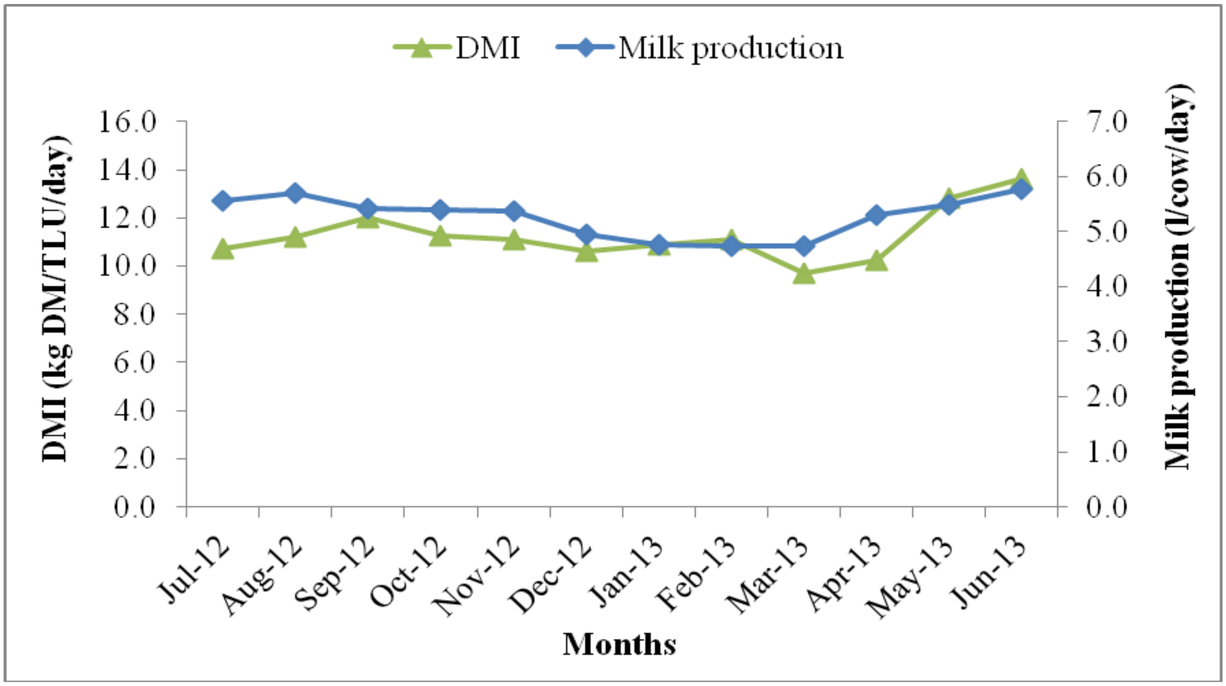

Figure 9a: DMI (kg/TLU/day) and milk production (litres/cow/day)

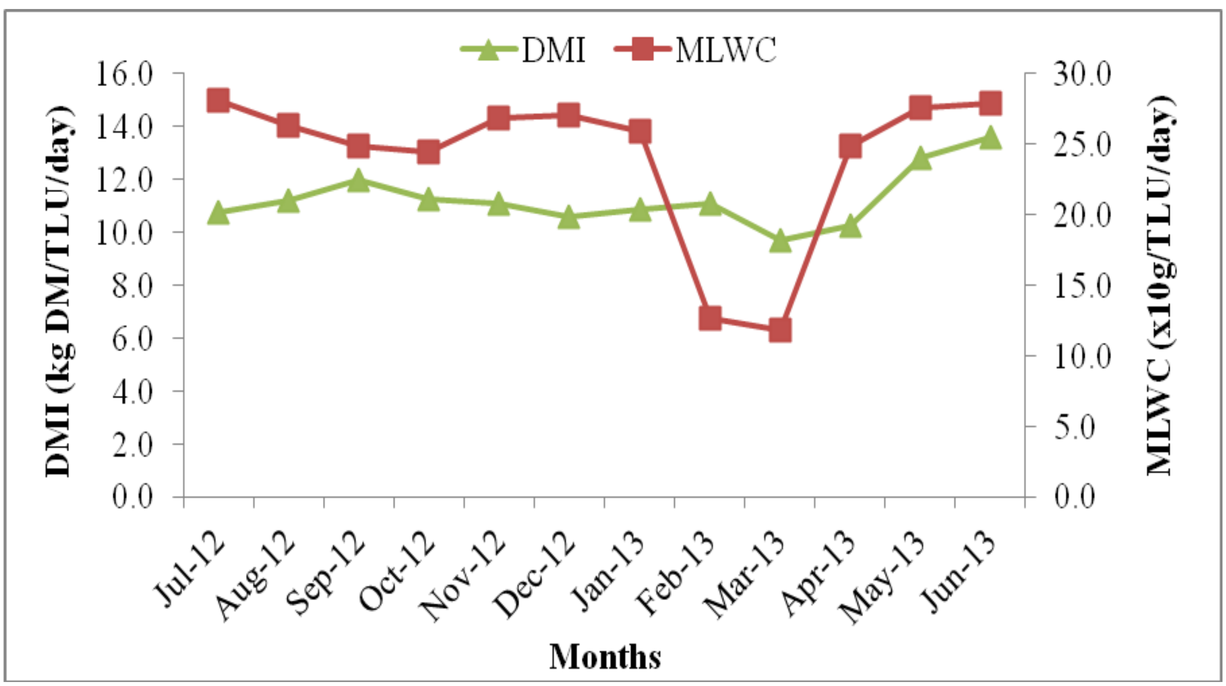

Figure 9b: DMI (kg/TLU/day) and MLWC (x10g/TLU/day)

Daily milk yield was used as an indication of quality and amount of feed offered to the lactating animals. The milk production curves did not follow the DM availability throughout the year (Figure 9a). During the months of November – February milk yield decreased while DMI intake increased. DMI and milk production rose from July – August. In the wet short rains season (October – December) some cattle were stall fed on lush natural pastures grasses in late December crop harvesting started and extended to January. Crop residues like maize stover and bean haulms were stored for feeding from January – March which marked the onset of long rains seasons. The variations in milk yield could be attributable to variations in DM availability. This was in agreement Mureithi *et al*. (1998) and Assefa *et al.* (2007) that seasonal availability of natural forages and profitability of the enterprise affected adoption of dairy technologies.

The greatest shortage of feed was experienced from January – March, especially if the short rains failed, when dairy cows were fed on poor quality by-products such as maize stover, mango leaves and dry grass from fallow land. However, in February – March (late dry season) and April (onset of long rains season), feed availability was more acute. Natural pastures were not harvested for storage and were fed when overgrown. Despite the increase in DM availability, the crop residues and natural pasture were of low quality hence the reduction in milk production. This was in agreement with Butterworth (1984) that during rainy season pastures are available in higher quantities and show good nutritional quality whereas dry season’s pastures have poor nutritional quality with high fiber and low protein contents, which often results in seasonal weight loss. The resulting nutritional stress leads to decreased productivity expressed through low calving rate, low birth weight, high calf mortality, low weaning weight, reduced mature body size, low growth rate, delayed maturity and more importantly, low milk production

(Muinga *et al.,* 1999; Wanjala and Njehia, 2014). Field observations during the study showed that, at the onset of the dry season, animals preferred feeding on mixtures of weeds (*Commelina sp., Asystacia sp.* and others) growing naturally in the farm environment to low quality crop residues. As result, the effects of fodder growth during the long rains season were felt during the following short rains dry seasn and short rains season.

Except during the short rains dry season, the DM availability was closely related with MLWC (Figure 9b). The animals lost weight during the dry season as the feed available was of low quality. In most farms, even during the rainy season the amount of fodder available for livestock was inadequate in both quality and quantity. A short wet season is often associated with a long dry season during which the decline in feed quality may cause weight loss. This situation is acute during the dry season when animals are underfed and often malnourished (Minae and Nyamae, 1988; NARP II, 1993). During this season browse tree legume like *L. leucocephala* should be exploited due to both availability and high supplemental value, especially protein (Shelton, 2004). Due to their, deep rooted nature of these browse species, they are able to tap water and nutrient resources deep in the soil profile and remain available even during the dry seasons.

In the study area, 55.2% of the available roughages consisted of natural pasture grasses, characterized by low CP of 84.1 - 97.1 g/kg DM which would adversely affect rumen microbial activity (Van Soest, 1982). During the long dry season, quality of much of the feeds was so poor that intake was below 11.7 kg DM/day required for maintenance resulting in animal weight loss. Napier grass supplied 15.1% of the feed resources and had a CP of 86.4 g/kg DM (Table 33). In small-scale farms in Kenya, feeding of napier grass was associated with low live weight gains of about 0.21 kg/day on young stock fed on napier grass of CP less the 80 g/kg DM (Gitau *et al.*, 1994).

The relationship between milk production and MLWC in the study area are shown in Figure 10.

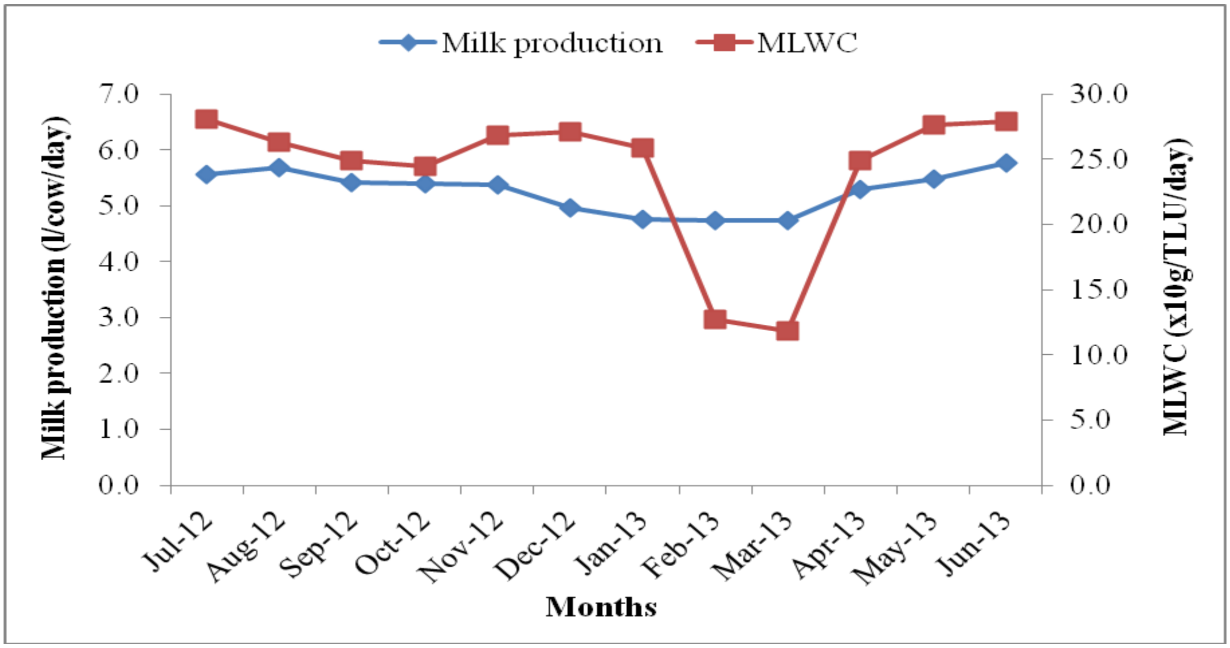

Figure 10: Relationship between milk production and MLWC

Animal productivity such as milk production and live weight change (LWC) is a function of feed availability and intake, nutrient concentration, digestibility and metabolic efficiency (Cherney and Mertens, 1998). Milk production and MLWC had similar pattern except from July - September where former increased while the latter decreased. In the study area, over 80% of the feed resources consisted of maize stover, napier grass and natural pastures, characterized by low quality (CP 72.2 - 97.1 g/kg DM). Natural pastures had 84.1 g/kg DM CP and provided 35.7% of the feed resources requirements underlying the inability of farmers to feed animals adequately with high quality feeds throughout the year.

The average monthly rainfall (mm) and minimum and maximum temperatures (°C) for Coastal Lowlands of Kenya varied as shown in Figure 11.

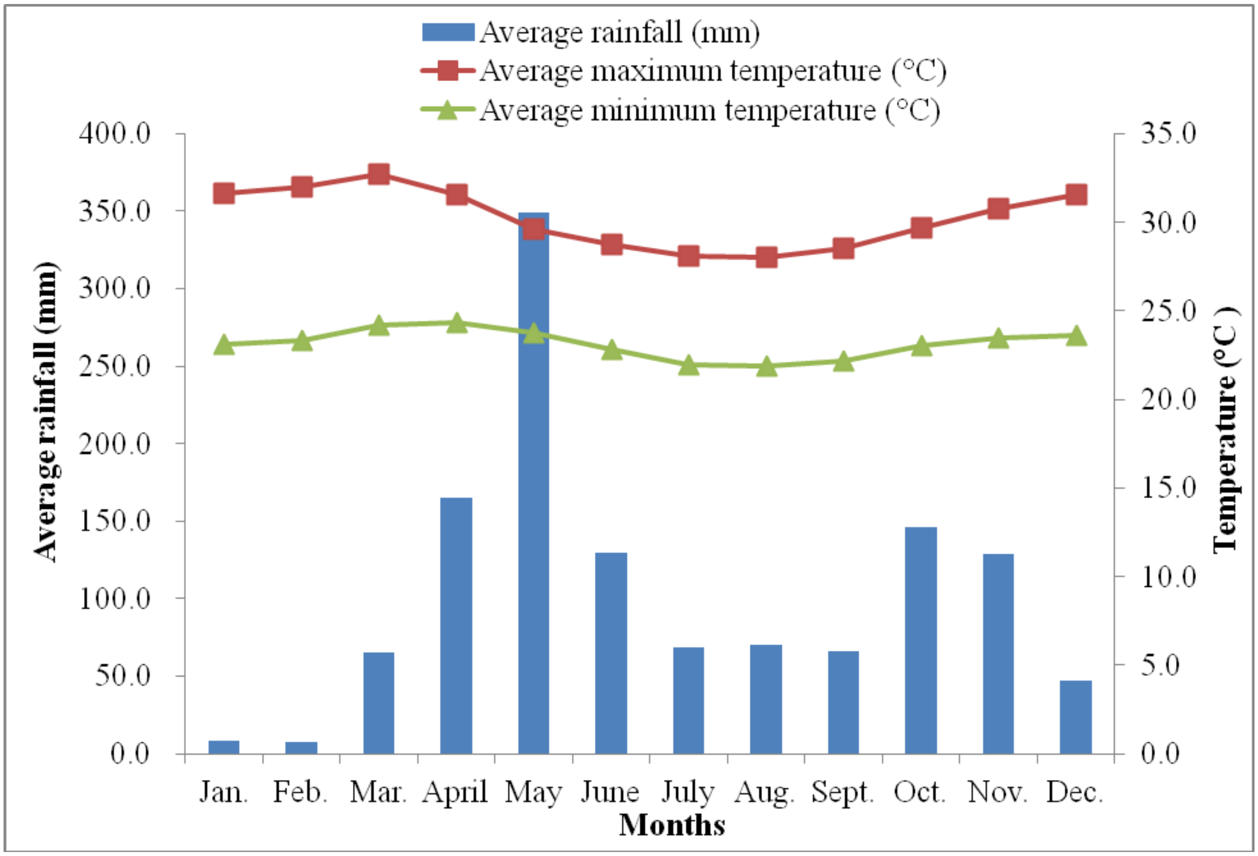

Figure 11: Average monthly rainfall (mm) and minimum and maximum temperatures (°C) for Coastal Lowlands of Kenya for the period 2005-2014

The rainfall is bi-modal, with the long rains between April and June and the short rains from October to December. Highest rainfall figures of 349.3 mm were recorded in May which marked the peak of rainy season and lowest in February at 7.6 mm. Mean annual temperature ranged from 25°C to 28.5°C, with maximum temperature at about 32°C during the months, January to April. The quantity and quality of the forage produced is likely to be affected by impact of temperature and rainfall variability due to changes in forage growth and dry matter (DM) yield (Appendix 2). There is a relationship among heat stress, declines in physical activity and the associated direct and indirect declines in animal feed intake (Morton, 2007). When temperature increases from 16 to 32oC, dry matter intake decreases by 18% and subsequently milk yield decreases by 32% (Chase, 2009). The stage of maturity at which the crop is cut is a major determinant of quality and relationship between increasing quantity and declining quality would continue to be of major economic importance. Therefore, increase in lignification of plant tissues reduces the digestibility and the rates of degradation of plant species (Leng, 1992). This condition may consequently lead to reduced nutrient availability for animals and ultimately to a reduction in livestock production (Thornton *et al.,* 2006). Decline in rainfall received lead to soil moisture deficits which reduces DM yield and affect also the stage of maturity for forage. However, the alterations in climate may be favourable to conservation and reduce losses during either silage or hay-making (Rowlinson, 2008).

Effect of pooled feed use on herd size, MLWC, milking animals, MMP and MDMI are shown in Table 51.

Table 51: Effect of pooled and optimum feed use on some production parameters

Parameters	Seasons	HS (TLU)	MLWC (g/TLU /day)	Milking animals (TLU)	MMP (litres/cow/ day)	MDMI (kg/TLU/day)
All feeds used	Season I	1,462	264	595	5.6	11.3
	Season II	1,462	261	610	5.2	11.0
	Season III	1,462	168	549	4.7	10.6
	Season IV	1,462	268	488	5.5	12.2
Optimum use (100% DM used)	Season I	1,131	274	460	5.8	11.7
	Season II	1,100	278	459	5.6	11.7
	Season III	1,055	187	396	5.3	11.7
	Season IV	1,222	257	408	5.3	11.7

HS - herd size; TLU - Tropical Livestock Unit; MLWC - mean live weight change; MMP - mean milk production; MDMI - mean dry matter intake; Season I: July - September (2012); Season II: October - December (2012); Season III: January - March (2013) and Season IV: April - June (2013).

Except in the HS, the optimum feed use model results closely resembled the actual performance when feeds were pooled in the study area. When all feed sourced on-farm and off-farm was considered per season at assumed constant TLU of 1,462, the MLWC ranged from 168 - 268 g/TLU/day for the whole herd, MMP ranged from 4.7 - 5.6 litres/cow/day and MDMI ranged from 10.6 - 12.2 kg/TLU/day. This was within MDMI range of 8.8 and 9.6 kg/head/day from Napier grass (*Pennisetum purpureum*) which is the main fodder source, in the coastal region (NDDP, 1994). However, it compares poorly with the estimated daily DM requirement of the common dairy breeds of 14 - 17 kg/head/day (NDDP, 1992a), suggesting a large feed deficit.

Feed deficit occurred in seasons I, II and III as the MDMI of 11.0, 11.3 and 10.5 kg/TLU/day was below 11.7 kg/TLU/day required to meet the cattle maintenance, production and reproduction requirements. This was an indication that at the current feeding levels, the animals in the study area were fed below their requirements as was reflected in the feed deficit in seasons I, II and III respectively, hence low milk production and MLWCs. As such, in coastal lowlands where most feeds are of low quality, optimum benefits from livestock could be obtained by selective utilization of quality feeds, through proper storage and carry-over systems. In addition, with increasing intensification of farming through zero-grazing, development and research on strategies to diversify feed resources on farms has the potential to enhance milk production.

In the model, available feed resources sourced off-farm and produced on-farm were characterized according to DM on seasonal basis. At optimum use of feed (100% use of DM produced on-farm and sourced off-farm) per season, the HS ranged from 1,055 - 1,222 TLU at 11.7 kg/TLU/day of feed in seasons I and IV respectively. Mean live weight changes (MLWC) and mean milk production increased with decreasing herd size. Milk production per cow per day increased and ranged from 5.3 - 5.8 litres with reduced herd size probably because of low quality of feeds. The optimum feed use model predicted mean live weight changes (MLWC) with carry-over of feed resources for the optimum number of TLU at 187 - 278 g/TLU/day. Even in times of excess feed supply in season IV, such predicted weights are difficult to achieve and could be attributed to low quality of feed. Actual herd size at all feeds use was 1,462 TLU which was lower than the predicted HS that could be supported when all feeds were pooled in all seasons. A similar trend was observed in the number of milking animals. This clearly indicated that except for season IV, the DMI was inadequate to support the 1,462 TLU in farms.

In sub-Saharan Africa, the demand for milk and meat is expected to grow by 3.9 percent and 3.2 percent per annum between 1997 and 2020 (Rosegrant *et. al*., 2001). These trends in food demand have important implications for natural resources that provide essential support to life and economic processes. The increased demand can only be achieved by a combination of expansion in animal numbers, increased production per animal and agricultural crop (Steinfeld *et. al*., 2006). The projected increase in production cannot be attained through feeding more of the biomass, but by providing good quality feeds. The suggestion by Winrock (1992) that livestock production in developing countries in the tropics could be considerably increased by using all feed resources is not supported by the results of this study. However, for some farmers, reduction of herd size may conflict with other functions of livestock such as savings and capital asset accumulation (Winrock, 1992). In the study area, keeping a large number of animals is associated with high risks of losses due to deaths during periods of feed shortages and farmers did not adjust their herd size according to fluctuations in feed supply.

5.5: Conclusions

Cattle were fed predominantly on naturally occurring forages (e.g. grasses and leaves), crop residues and agriculture by-products and in some areas on planted forages (e.g. Napier grass, tree legumes and other legumes) whose DM production and intake varied seasonally. These factors made it difficult to formulate feeding strategy based on stipulated feeding standards. Natural pastures were the most readily available feed resource at 55.2%. Despite feed management strategies aimed at reducing the seasonal variations in the feed quality, it still remains a major constraint. Feed supply during the dry seasons, which in the study area is most severe in the periods from January to mid March and August to mid October, constitutes an important limitation to animal production. In areas where most feeds are of low quality, optimum benefits from livestock can be obtained by selective utilization of quality feeds, higher intake of DM through various vegetative and concentrate supplements to the basal diet and through proper carry-over systems. The results of this study suggest that animal productivity might be increased at the current feed supply by reducing current herd size (HS) to a level of optimum feed use, or, alternatively, by increasing production of quality feed. In addition, with increasing intensification of farming through zero-grazing system occasioned by decreasing land sizes, a strategy to diversify feed resources on farms has potential to enhance quantity of milk produced. Research shuold be focused on working on a diverse number of improved fodder plant varieties and threshold combinations to meet livestock feed requirements while promoting stability and sustainability. Non-nutritional factors such as heredity, parity and diseases should be adequately addressed as these have significant effect on milk production and sometimes may overshadow nutritional effects.

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6.0: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1: General Discussion

Small-scale dairy cattle’s farming is an important source of livelihood in Coastal Lowlands of Kenya. Due to reliance on rain-fed forage production, the main challenge has remained availability and poor quality of feeds leading to low milk production and lower income. To determine the effect of seasonality on availability and quality of feed resources on small-scale dairy cattle production systems, a cross-sectional survey followed by a longitudinal survey was conducted in Kwale and Kilifi counties. From the study, feed type, composition and availability varied within farm and between seasons and animal productivity followed this pattern.

At the farm level, there are many interacting factors which may either be dependent or inter dependent. Therefore, it is important to understand these factors in order to develop feasible improvements for a particular farming system. Two-Step cluster analysis was used to classify farmers using variables selected *apriori* and identified four distinct clusters. The validity of the clusters was tested by analyzing separate sub-samples according to counties and results compared. The resulting clusters were profiled using discriminant analysis to determine the main distinguishing features that households in each cluster have in common and those characteristics that differ across clusters using demographic and socio-economic variables not previously considered in the cluster procedure. Each cluster had unique characteristics, constraints and opportunities, which help define research and development policy priorities. The majority of farmers were in cluster 1. In cluster 3, off-farm incomes played an important role in income stabilization. The findings provided background information for identifying promising interventions for farmers in different clusters, available feed resources and their dry matter yields, nutritive value, DM intake and nutrient requirements and deficit during different seasons in small-scale dairy cattle farms in the study area. The diversity in clusters considered suggests that different prescriptions will be needed to improve productivity based on opportunities and constraints identified and prioritized in dairy cattle value chain.

Chemical analysis of the common roughages showed that most of them had low to moderate CP levels of 72.2 – 97.1 g/kg DM. The cell wall contents (NDF and ADF), represents the most important fraction of dry matter for all roughages, ranged from 333.6 to 728.8 and from 357.4 to 478.4 g/kg DM respectively. Pasture grasses constituted 55.2% of basal feed resource and had a CP content of 84.1 – 97.1 g/kg DM indicating that dairy cattle are fed on low quality roughages especially in the dry season. *L. leucocephala*, *A. gangetica* and *C. benghalensis* had CP content of more than 100 g/kg DM and low NDF content of 333.6 – 493.4 g/kg DM which would make them good protein supplements to low quality roughages in the study area.

At farm level, the combination of DM yield and observed DM intake could form the basis for estimating the number of livestock units that can be supported by nutrient yield from the available land. Addressing the challenges of dairy cattle feeding, could thus guarantee a sustainable livelihood to small-scale dairy farmers in Kwale and Kilifi counties. Throughout the year, the animals are fed on a similar plane of basal diet from season to season with their DM intake significantly reduced in dry seasons (January - March and July - September) when roughage quantity and quality are low. Despite their relatively poor nutritive value, maize stover and natural pastures whose quality depends on stage of maturity were the main basal feeds through out the year. This results in a low quality basal diet, a less dense and less vigorous rumen microflora and hence very low DM digestion observed in this study. The dry seasons and short rain season (October - December) were the crucial periods for high quality forage supplement intervention for the cattle due to high reliance on natural pasture grasses, the least nutritive of the roughage components during the this period.

The roughages had significant variations ($P < 0.05$) in DM and CP rumen degradability characteristics. Except *C. plectostaychus, P. coloratum* and *P. maximum,* all the other roughages can contribute considerably as ruminant feed resources as their DM disappearance was above the 40% value after 48 hours of incubation which is to be considered satisfactory. The relatively high solubility in *L. leucocephala* and *C. benghalensis* reveals their potential of being good sources of more nutrients for microbial growth. Overall, none of the pasture grasses made it to be a good nutritional quality grass to supply nutrients to the dairy cattle production systems in the Lowlands of Kenya as sampling and harvesting of pasture grasses was not based on maturity of phenological stage. The differences in chemical composition, DM and CP disappearance between roughages are attributable to individual characteristics of each, the most important being species and stage of maturity. These results could be important when considering ration feed formulation and supplementation strategies for dairy cows and could be used to develop an integrated forage production and livestock nutrition management plan to provide sufficient year-round feed supply based on requirements and supplementation strategies.

6.2: Conclusions

1. Characterization of small-scale farmers into clusters using the variables selected *apriori* could assist in defining research objectives and development priorities based on opportunities and constraints identified within each cluster.

2. The nutritive value of the available pastures and forages was classified as low to moderate. This was attributed to the stage at which the farmers harvested their forage.

3. Except *C. plectostaychus*, *P. coloratum* and *P. maximum*, all the other roughages can contribute considerably as ruminant feed resources as their DM disappearance was above the 40% value after 48 hours of incubation which is to be considered satisfactory.

4. Feed quantity was inadequate and rarely met the nutrient demands of lactating dairy cows, especially during the dry season. To improve productivity, there is need to reduce the herd size, improve the quality of the cows and increase use of concentrate.

6.3: Recommendations

1. Appropriate interventions strategies should consider all variations in the factors of production along dairy cattle value chain, their relationships and patterns among the clusters. Future research using other delineating variables across the study sites should be considered in the region. There is need to improve milk productivity in order to uplift the living standards of the region. Development of strong institutional linkages, provision of credit facilities, support for commercial rearing of dairy breeding stock and capacity building of extension agents and

farmers will a necessary prerequisite to improve performance of dairy herds in order to bridge the the gap between the annual milk demand and production.

2. Farmers' shuold be encouraged to harvest pasture grasses at bloom-milk stage in order to take advantage of their rich nutrient supply. This can be done through capacity building of extension agents and farmers and support feeds diversification programmes in order to improve performance of dairy herds.

3. The data provided by this study on IVDMD, DM and CP degradation kinetics will facilitate making appropriate choices for feed ration formulation and supplementation strategies at the farm level. However, animal feeding trials under farm field conditions to make use of the roughages in the form they are utilized by the animals will be required.

4. The available feed resources are seasonal and there is need to even out the distribution throughout the year through development of an integrated forage production and livestock nutrition management plan to provide sufficient year-round feed supply based on animal requirements and supplementation strategies. At the same time, research on disease resistant and high yielding pasture grass varieties to boost the yields of crops and livestock should be encouraged and with more emphasis in conservation methods.

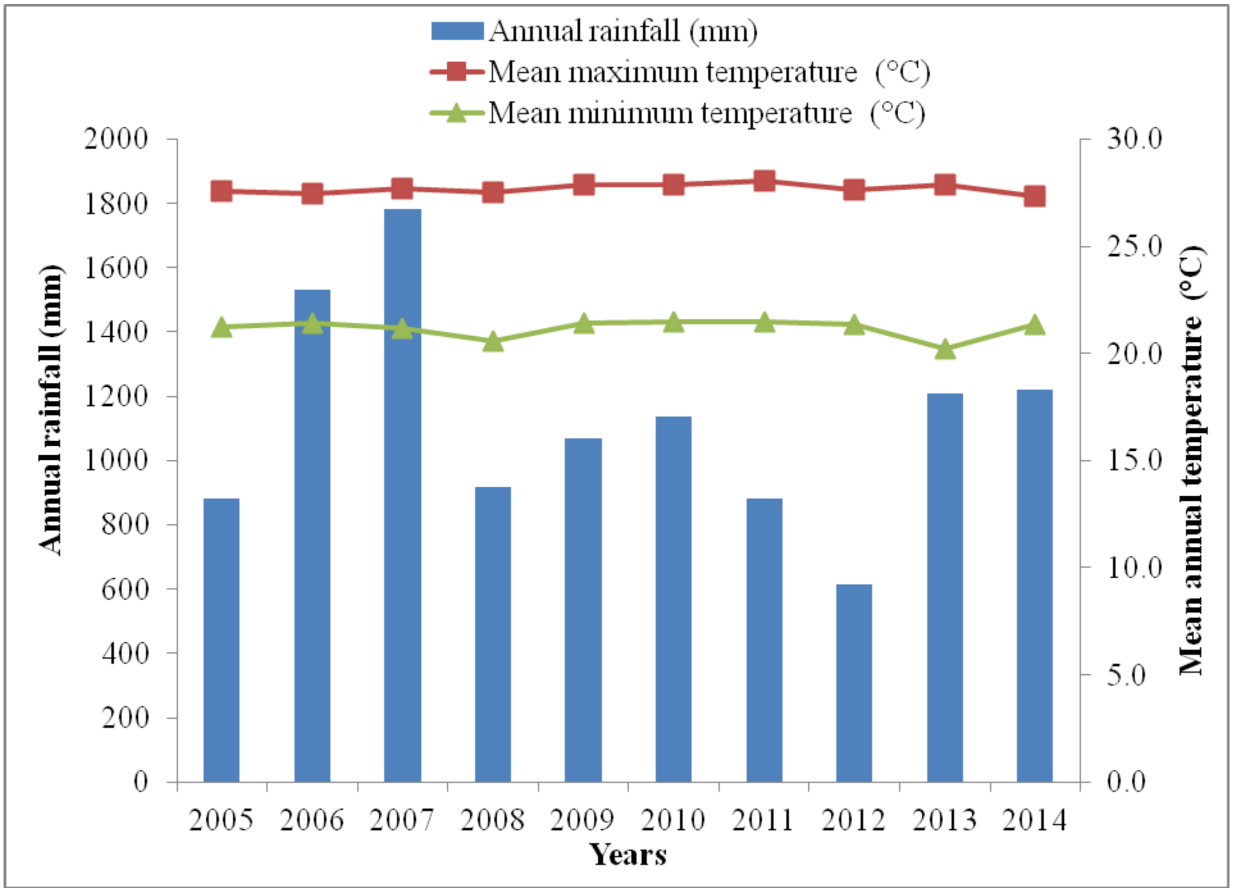
7. LIST OF APPENDICES

7.1: Livestock Distribution by Province in Kenya

Province	Cattle	Sheep	Goats	Camels	Donkeys	Pigs	Indigenous chicken	Commercial chicken	Bee hives
Coast	959,965	467,439	1,571,728	51,045	31,916	5,243	1,599,696	521,864	45,239
Nairobi	54,546	34,717	46,837	20	12,824	29,976	279,397	342,788	7,585
Central	1,125,905	664,237	531,209	231	35,516	91,977	3,039,786	2,489,837	95,972
Eastern	2,260,161	1,890,898	4,729,057	248,634	304,249	43,480	4,107,618	544,812	842,857
North Eastern	2,775,208	4,264,155	7,887,586	1,700,893	382,345	68	422,899	71,313	59,189
Nyanza	1,748,670	495,055	961,269	59	60,793	27,612	5,605,478	501,056	48,124
Rift valley	7,479,807	9,079,380	11,750,521	968,192	988,647	48,495	6,557,262	1,339,395	706,765
Western	1,063,512	233,725	263,946	2,037	16,229	87,838	4,144,351	259,977	36,765
Total	**17,467,774**	**17,129,606**	**27,742,153**	**2,971,111**	**1,832,519**	**334,689**	**25,756,487**	**6,071,042**	**1,842,496**

Source: KNBS (2010b)

7.2: Annual rainfall (mm) and minimum and maximum temperatures (°C) for Coastal Lowlands of Kenya for the period 2005-2014



(Source: Kenya Meteorological Department)

7.3: Cross-Sectional Survey: Coastal Lowlands of Kenya Data Collection Questionnaire

KARI-MTWAPA AND UNIVERSITY OF NAIROBI PROJECT

GENERAL INFORMATION

Name of enumerator: ___________________________________ Date: ___/____/ 2012
County: __________________District: __________________ Division: __________________
Location: ______________________________ Sub-Location: ___________________________

A: FARMER DEMOGRAPHIC CHARACTERISTICS

1. Name of Respondent ____
2. Respondent **position** in household: Husband [ ]; Wife [ ]; Son [ ]; Daughter [ ]; Hired farm hand [ ]; Other specify [ ] ___________
3. **Age** of respondent: _____________ years
4. **Gender** of respondent: Male [ ]; Female [ ]
5. Provide the following **details** about the **household head** using the following:

Gender	**Primary activity**	**Education level**
1= Male	0 = None	0= No formal education
2= Female	1 = Civil Service	1 = Primary Level
	2 = Farm worker	2 = Secondary level
	3 = Businessman	3 = Adult education
	4 = Farming	4 = Technical college
	5 = Private sector employee	5 = University
		6 = Others (specify)

Gender	**Age (years)**	**Work**		**Primary activity**	**Years of farming experience**	**Education level**	**Availability for farm work (%)**
		Off-farm	**On-farm**				

6. Give the **number** of **household members** (including household head) living **permanently** on the farm?

	<18years	**18-35 years**	**35-55 years**	**>55 years**
Male				
Female				

7. Indicate **who** in the household is **primarily responsible** for carrying out the following **tasks**: **Choose from: 1** = Household head; **2** = Adult males (other than HH head); **3** = Adult females (other than HH head); **4** = Wife; **5**= Children; **6** = Casual labourers; **7** = Long-term labourers

Cattle activities	**Main people doing the work**
1. Grazing animals	
2. Cut and carry forages (harvesting)	
3. Cut and carry forages (feeding animals)	
4. Planting forages	
5. Weeding forages	
6. Manuring forages	
7. Cleaning cow sheds	
8. Obtaining AI/ veterinary services	
9. Milking cows	

10. Fetching water for animals	
11. Spraying/ dipping animals	
12. Delivering milk to markets	

8. In the **last 12 months**, have you employed any **casual labourer** on the farm? Yes [_]; No [_]
   If **YES**, how **much do you pay per day**? Males [________]; Females [________]
9. How many **hours per day** is a **normal work day** for casual labourers? __________________
10. In the **last 12 months**, have you employed any **long-term farm labourer** on the farm? Yes [__]; No [__]
    If **YES**, how **much do you pay per month?** Males [________]; Females [________]

B: CURRENT FARM ACTIVITIES

11. What are your **main objectives** in farming? (rank 1, 2, 3, … in order of importance)

Objective	Rank
Milk for home consumption (food supply)	
Milk for sale (source of income)	
Manure supply	
Social status and prestige	
Others (specify)	

12. How **much land** do you have **ACCESS to** in **acres**? _________________
13. Of the land you have **ACCESS** to, have many acres do you **OWN**? _________________
14. If **different parcels,** list and state the **acreages** of various **parcels** in the table below.
    Mark **"X"** against the land tenure arrangement.

Land parcel number	Acres	Estimated distance in kilometers from the homestead	Tenure arrangement			
			Freehold	Leasehold	Rented	Communal
Parcel 1						
Parcel 2						
Parcel 3						
Parcel 4						

15. Of the land you have **ACCESS to** indicate the **acreage** under **farming or grazing or cut-carry fodder** in each parcel.

Land parcel number	Land utilization	Tenure arrangement (acres)			
		Freehold	Leasehold	Rented	Communal
Parcel 1	Farming				
	Cut and carry fodder				
	Grazing				
Parcel 2	Farming				
	Cut and carry fodder				
	Grazing				
Parcel 3	Farming				
	Cut and carry fodder				
	Grazing				

C: FORAGE PRODUCTION AND CONSERVATION

16. What **production system** do you use for your **dairy animals**?

Production system	Dry season	Wet season
Zero-grazing only		
Tethering		
Semi zero-grazing		
Free grazing		

17. For **grazing** indicate which **types of land are grazed** in different seasons?
Place “**X**” in the boxes which correspond to the responses.

Source of grazing	**Long dry Jan-Mar**	**Long wet Mar-May**	**Short dry Jun-Aug**	**Short wet Sept-Dec**	**All year**
Own pasture/ un-cropped land					
Own post harvest cropped land					
Neighbours post harvest cropped land					
Public land pastures					
Rented land pastures					

18. For **cut and carry fodder** and **crop residues (zero-grazing)** indicate which **types of feeds are offered in** different seasons?
Place **“X”** in the boxes which correspond to the responses.

Cut-and-carry fodder and Crop residues	**Long dry Jan-Mar**		**Long wet Mar-May**		**Short dry Jun-Aug**		**Short wet Sept-Dec**		**All year**	
	On-farm	Off-farm	On-farm	Off-farm	On-farm	Off-farm	On-farm	Off-farm	On-farm	Off-farm
Napier grass										
Green maize stover										
Dry maize stover										
Roadside grass										
Cassava roots										
Cassava leaves										
Oilseed byproducts										
Forage legumes										
Fodder trees										
Straw/Hay										
Other crop residues										
Gliricidia										
Leucaena										
Clitoria										

19. Do you **experience a shortage of feeds** produced from your farm? **YES** [___]; **NO** [___]
If **YES,** place “**X**” in the boxes which correspond to the responses.

	Long dry Jan-Mar	Long wet Mar-May	Short dry Jun-Aug	Short wet Sept-Dec	All Year
Now					
5 years ago					
10 years ago					

***If on this farm less than 5 years state number of years and ask same question.**

20. **Rank the 3 major strategies** you apply during these **periods of feed shortage** and what you did? (First - 1, second - 2, third – 3 in order of importance)

Strategy	Now	5 Years ago	10 Years ago
Use stored silage			
Feed less to all animals			
Feed less to certain categories of animal			
Selling some animals			
Rent grazing land			
Send cattle on transhumance			
Reduce herd size			
Purchase fodder			
Purchase concentrate feed			
Feed tree leaves/forage not normally used			
Delay cutting of napier grass			
Others (specify) ______________________			

***If on this farm less than 5 years state number of years and ask same question.**

21. Have you ever **conserved any forage** in your farm? **Yes** [ ]; **No** [ ]
    If **YES**, state **when** and **what form** you first **conserved forage**? Hay [ ]; Silage [ ]

22. For **HAY**, when was the **last conservation**?

Year	Season (1= wet; 2= cold)	Quantity (No. of bales)	Type of forage materials

23. Have you been t**rained** on **hay making**? **Yes** [ ]; **No** [ ]
    If **YES, when, for how long** and **by whom**?

Type of training	When (date)	Duration (days, wks months)	By whom
Hay making			

24. Do you think you require **more training** on hay making? **Yes** [__]; **No**= [__]
    If **YES**, ask why? ____
    If **NO**, ask why? ____

25. For **SILAGE**, when was the **last conservation**?

Year	Season (1= wet; 2= cold)	Quantity (tons)	Types of forage materials used

26. Have you been **trained** on silage making? **Yes** [ ]; **No** [ ]
    If **YES, when, for how long** and **by whom**?

Type of training	When (date)	Duration (days, wks months)	By whom
Silage making			

27. Do you require **more training** on silage making? **Yes** [___]; **No** [___]
    If **YES**, ask why? ____
    If **NO**, ask why? ____

28. What **fodder crops** do you grow and what are their respective **acreages**? Are the crops grown as **mono crops** or are they **intercropped**. Indicate **when** and **what parts** are available as livestock feed.

Crop	Acreage	Monocrop or intercrop	Available long rains	Available short rains	Parts available as livestock feed
Napier grass					
Gliricidia					
Leucaena					
Clitoria					
Cassava					
Rhodes grass					
Maize					
Madafu					
Forage legumes					
Fodder trees					
Others (specify)					

D. LIVESTOCK INVENTORY

29. Record the **number of animals** for the different species kept on the farm (**except cattle**).

Kept on the farm	Goats					
	Local	Dairy	Sheep	Donkeys	Pigs	Rabbits
Milked **1**= Yes, **2**= No						
Number of animals milked						
Number of dry animals						
Other adult males (> 3 months)						
Other adult females (>3 months						
Young females (< 3 months)						
Young males (< 3 months)						
Total						

30. Record the **heart girth measurements** in **centimeters of ALL** animals **except rabbits** in **Question 29** above on a separate sheet of paper.

	Animal name	Sex (1 = male; 2 = female)	Animal type	Heart girth (cm)

31. Record the precise population of **cattle** kept on the farm

Owned by HH		Local	Dairy Local Cross	High grade dairy
Number of cows milked				
Number of dry cows				
Bulls (> 3 years)				
Immature bulls (3 months -3 years)				
Heifers				
Suckling calves (< 3 months)	Male			
	Female			

Total			

32. Record the **heart girth measurements in centimeters of ALL CATTLE** in **Question 31.**

	Animal name	**Sex (1 = male; 2 = female)**	**Animal type**	**Heart girth (cm)**

33. In the last **12** months, **did some cattle die or were slaughtered**? **Yes** [___]; **No** [___]

If **YES**, please record the number of **cattle** which **died** or were **slaughtered** in the last **12** months and the **reason why using codes below**?

Cause of death/ Reasons for slaughter: **1** = Disease; **2** = Injury/ accidents; **3** = Poisoning; **4** = Bloat; **5** = Meat; 6 = Others (specify)_______________

Cattle category		**Number died**	**Cause of death**	**Number slaughtered**	**Reasons for slaughter**
Cows in milk					
Dry cows					
Heifers					
Bulls (> 3 years)					
Immature bulls (1- 3 years)					
Pre-weaned calves (3 months – 1 year)	Males				
	Females				
Suckling calves (< 3 months)	Males				
	Females				

34. In the last 12 months, **did you sell some cattle**? **Yes** [___]; No [____]

35. Please record the number of **cattle** which were **sold** in the last 12 months?

Reasons for selling: **1** = needs cash; **2** = old age; 3 = disease; **4** = culled (poor performances); **5**= other (specify)

To where: **1** = within the division; **2** = within the district; **3 =** outside the district

To whom: **1** = individual farmer; **2** = group of farmers; **3** = butcher; **4** = other (specify): _______

		Number sold	**Age (years)**	**Reasons for selling**	**To Where**?	**To Whom?**	**Average price Ksh.**
Cows in milk							
Dry cows							
Heifers							
Bulls (> 3 years)							
Immature bulls (1- 3 years)							
Pre-weaned calves (3 months – 1 year)	Males						
	Females						
Suckling calves (< 3 months)	Males						
	Females						

36. In the last 12 months, **did you buy some cattle**? [____] 1 = Yes 2 = No

37. If **YES,** please record the number of **cattle** which were **purchased** in the last 12 months?

Reasons for purchasing: 1 = replacement; 2 = to obtain manure for crop production; 3 = social prestige; 4 = to increase income through the sale of more milk; 5 = other (specify)

To where: **1** = within the division; **2** = within the district; **3 =** outside the district

From whom: 1 = individual farmer; 2 = co-operative society; 3 = large dairy farm; 4 = farmer group; 5 = other (specify):

Category of cattle		**Number purchased**	**Age (years)**	**Reasons for purchasing**	**From Where?**	**From Whom?**	**Average price Ksh.**
Cows in milk							
Dry cows							
Heifers							
Bulls (> 3 years)							
Immature bulls (1- 3 years)							
Pre-weaned calves (3 months – 1 year)	Males						
	Females						
Suckling calves (< 3 months)	Males						
	Females						

38. Do you keep **ANY written records** of cattle production (e.g. calving or milk production etc) **Yes [___]; No [____]**

If **YES**, may I have **a look** at them? Indicate the **types** of written records kept.

If **NO, give reasons for not** keeping records.

D: DAIRYING

39. Indicate the year when s**tarted dairy farming**? [______]
40. Indicate the year when first start **selling surplus milk**? [__ __]
41. How did you get your **first dairy cow(s)** in the herd? [________]

Choose from: **1**= Purchased own cow; **2**= Obtained cow from a development project directly or indirectly e.g. HPI; **3** = As a gift from relatives/friends; **4** = Through A.I on local heifer/ cow; **5** = Through borrowed/rented bull on local heifer/cow; **6** = Other (specify) ___

42. Rank the reasons why you **wanted improved animals**? First [___] Second[___]Third [___]

Reasons: 1= Better looking animals; **2**= Increased milk production for home consumption; **3**= Stronger animals for traction etc; **4**= Extension officers advice; **5** = Increased status /social standing, personal pride, fashionable trend (from neighbours); **6**= Increased milk production for marketing; **7**= A condition to getting a loan

43. Do you want to **increase the amount of milk you produc**e? **Yes**[___]; No [___]
44. If **YES**, **how do you plan to do it**? First method [ ]; Second method [ ]; Third method [ ]

Methods: **1** = improve the grade of animals; **2** = produce more feed; **3** = buy more feed; **4** = increase number of dairy; **5** = spend more in controlling animal diseases; 6 = specify ______

45. If **NO, why not**? Main constraint [ ]; Second constraint [ ]; Third constraint [ ]

Constraints: **1** = lack of credit to buy more animals/ feed; **2** = low milk prices; **3** =lack of milk markets; **4** = lack of veterinary services; **5** = lack of A.I; **6** = disease incidences; **7**= others (specify)

46. How many **times a day do you milk**? [___]

47. **For each cow in the herd fill a row**.

	Cow information										**Total daily milk production (evening plus morning milk)**			**Most recent calf**		
No	**Name**	**Breed**	**Age (Years)**	**Age at 1st calving (months)**	**Number of carvings**	**Pregnant 1=Yes 2=No**	**Service 1= A.I 2=Natural**	**Last service date MM/YY**	**Previous calving date MM/YY**	**Date dried MM/YY**	**Peak after calving**	**Yesterday**	**Drying off**	**Sex**	**Calf in farm 1=Yes 2=No**	**If no, what happened**
1																
2																
3																
4																
5																
6																
7																

48. What is the **total milk per day** (refers to previous day's yield) and **utilization** by the **Household**?

Milk quantity [____] (Indicate the units: 1 = litre; 2 = bottle size (750ml); 3 = cup)							**Milk price (Ksh. /kg)**
Morning (AM)	**Evening (PM)**	**Total milk production**	**No. of animals milked**	**Used by Household**	**Used by Calf**	**Sold**	

CALF REARING

IF NO CALVES ON FARM PRESENTLY, RESPONDENT TO USE RECALL

49. At what **age** in **months** do you **wean** the calves**?**

Calves	**Age at weaning (months)**
Females	
Males	

50. Do you have **different feeding schedules** for males and females calves? **Yes [___]**; **No [___]**
51. How do you **feed** the males and females calves from **birth to weaning**?
52. Do you **castrate male calves** not selected for breeding? **Yes** [____]; **No [___]**
    If **YES,** why? ____
    If **NO,** why? ____

E: LIVESTOCK MANAGEMENT AND HEALTH SERVICES

53. Do you feed your dairy cattle with **commercial feeds,** and **agro-industrial by-products**? **Yes** [___]; **No [____]**

***Indicate the amount used per day using the key below**						
Dairy Meal	**Maize Germ**	**Maize Bran**	**Wheat Bran**	**Mineral Salts**	**Mineral salts**	**Remarks**
Key: 1. 1 kg Plastic Kimbo tin	**2. 2 kg Plastic Kimbo tin**			**3. 1 table spoonful**		

54. Is water always available to your animals throughout the day? **Yes** [___]; **No [____]**
55. If **NO**, how **frequently do you water** your cows? [__________]
56. Is water provided with the **same frequency** to all your cows? **Yes** [___]; **No [____]**
57. If **NO**, why?____
58. What is the **source of this water?** [______________________________]
59. If you collect water, what is the **distance** from farm to the source [___ ___] km.
60. List **4 major animal health problems** affecting your herd? 1.______________________, 2.________________________, 3. ____________________, 4, ___________________,
61. Please **rank** them (in decreasing order of importance) First [___]; Second [___]; Third [___]
62. Have your dairy cattle been **vaccinated** in the last **12** months? **Yes** [___]; **No [____]**
63. If **YES, name the diseases** that your dairy cattle have **vaccinated** against **based on local epidemiology.** [__________________] [______________________] [__________________]
64. When your **animals need management/health services** are they available? **Yes** [__]; **No [__]**
    If **YES**, how many **times** did you use them in the **last 12 months**?

Type of animal health service provider	**Number of yearly visits**
Self/ Neighbour with professional advice	
Self/ Neighbour without professional advice	
Government veterinarian/AHA	
Cooperative Vet	
Private veterinarian/AHA	
Herbalists	
Other animal health service providers (name)	

65. Have you used **any tick control measures** in your farm in **the last 12 months? Yes** [__]; **No [__]**

66. Which **tick control technique** do you typically use**?**

Place an **"X"** in boxes which correspond to responses.

Tick control technique	**Adults**	**Young stock**
Dipping		
Hand spray		
Hand wash		
Pour-on		
Other specify______		

67. Have you used any **anthelmintics** (dewormers) in the last **12** months? **Yes** [___]; **No [____]**

If **NO**, why? [_ __]

68. Which control measures do you apply for **Trypanosomiasis**? [______________________]

F: CREDIT, EXTENSION SERVICES AND ASSESTS

69. Have you **ever obtained long term credit** for your dairying activity? **Yes** [___]; **No [____]**

If **Yes**, how many years ago? ___________________________

If **No**, why not? ____

70. Indicate by a simple **"X"** which of the following services is available in your area

	Veterinary services	**Number of visits in last 6 months**	**AI Services**	**Number of visits in last 6 months**	**Livestock Extension Services**	**Number of visits in last 6 months**
Government						
Private						
NGO's						
Cooperative						
Agrovet						
Neighbor/relative						

71. What were your **three main sources of the information**?

	First choice	**Second choice**	**Third choice**
Extension officers			
KARI research station			
Library			
Local newspapers			
Internet			
Radio			
Others (specify)			

72. Are you a member of **any social organization**? **Yes** [___]; **No [____]**

If **YES**, which **ones and for how long**?

Organization	**Duration (years)**
Cooperative society	
Women group	

Farmers group	
Community Based Organization	
Men group	
Others (specify)______________	

If **NO**, why not? _______________________________________

73. How many times in the **last 5 years** have you attended

- A dairy farmer's field day? [___]
- An agricultural show anywhere? [____]

74. How many of these **assets** are available within your household? (**Tick the available assets**)

Asset	**Number**	**Asset**	**Number**	**Asset**	**Number**
Jembe		Oxen for traction		Bicycle	
Panga		Donkeys for traction		Motor bike	
Spade		Oxen carts		Irrigation pump	
Wheel burrow		Fodder store		Water well	
Tractor		Mobile phone		Radio	
Pick up		Silage pit		Television	
Lorry		Donkey carts		Hay boxes	

G: <u>HOUSEHOLD CASH INCOME AND CONSTRAINTS</u>

75. For the **different sources of income** to the household, **either rank or estimate amount** per month

For ranking: **1**= main source of income, **2**=2nd, **3**=3rd, **4**=4th, **5** = smallest source of income.

	Rank	**Income Kshs.**	**Per month**
Income from sale of dairy products			
Income from sale of poultry/eggs			
Income from sale of food crop products			
Income from sale of cash crop products			
Income from wages/salaries/non-farm activities			
Income from remittances from absent family members			

76. In which of the following groups do you estimate your **total household and farm income**, from all working members, business income, pensions and remittances from elsewhere [ ]

Total Household and Farm Income Categories **(Ksh / month**)

1= <2,500; **2**=2,500-5,000; **3**=5,000-10,000; **4**=10,000-20,000; **5**=20,000-30,000; **6**= >30,000

77. Among livestock products, compare the relative importance of their income to the household 1 = is < (less than), 2 is = (equal to), 3 is > (greater than)

Income from sale of live animals		Income from sale of milk
Income from sale of cow dung		Income from sale of milk
Income from sale of skins / hides / wool		Income from sale of milk
Other: _____________________________		Income from sale of milk

78. How much of household average monthly income is from Livestock (milk sales) Ksh______________ and off-farm income Ksh______________?

79. What is the **gender and number** of **casual** or **monthly labourers** working on the farm if any?

Gender of dairy worker	**<18years**	**18-35 years**	**35-55 years**	**>55 years**
Male				
Female				

80. Cost of hired of **casual** or **monthly** labour according to gender.

Gender of dairy worker	**Cost of labour**	**< 18years**	**18-35 years**	**35-55 years**	➢ **55 years**
Male	Casual				
	Monthly				
Female	Casual				
	Monthly				

84. Give the **farmer** an opportunity to ask a **few questions**.

Record them, answer those that you can and for additional information refer the farmer to nearest Livestock Production office and/or KARI-Mtwapa.

End of questionnaire
Asante sana

7.4: Longitudinal Survey: Coastal Lowlands of Kenya Data Collection Checklist

KARI-MTWAPA AND UNIVERSITY OF NAIROBI PROJECT			
A. INDIVIDUAL COW MIILK PRODUCTION CARD			
ENUMERATOR:			
COUNTY:	**DISTRICT:**	**DIVISION:**	
Farmer Name:		**Month:**	**Year:**
Cow name:	**Age (years):**	**Parity number:**	**Breed:**
Date of Last Calved	**Sex of the calf (1= Male; 2 = Female)**	**Where is the calf?**	

	Milk quantity (litres)					**Milk price /l**	**Remarks (Heat Signs, Sick, Deworming, Vaccination)**
Date	**Morning (AM)**	**Evening (PM)**	**Used by Household**	**Used by Calf**	**Sold**		
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
16.							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							

B. DAIRY COW FEED MANAGEMENT							
i. Feed Supplements Amounts							
Cow name(s):						Month:	Year:
	*Indicate the amount used per day using the key below						
Dates	**Dairy Meal**	**Maize Germ**	**Maize Bran**	**Wheat Bran**	**Mineral Salts**	**Any other (name)**	**Remarks**
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
16.							
17.							
18.							
19.							
20.							
21.							
22.							
23.							
24.							
25.							
26.							
27.							
28.							
29.							
30.							
31.							
Key: 1= 1 kg Plastic Kimbo tin; 2 =2 kg Plastic Kimbo tin; 3= 1 table spoonful; 4 = Any other measure (specify)							

Indicate the brands and /or company of various feed supplements					
	Dairy Meal	**Maize Germ**	**Maize Bran**	**Wheat Bran**	**Mineral Salts**
Date bought					
Price/ unit					
Date finished					

ii. Types and Amounts of Roughages Used				
Farmer Name:				
Roughages	**1.**	**2.**	**3.**	**4.**
5.	**6.**	**7.**	**8.**	**9.**
Cow name:			**Month:**	**Year:**

	***Indicate the amounts of ruoghages used per day using the key below**						
Dates	**1**	**2**	**3**	**4**	**5**	**6**	**REMARKS**
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
Key: 1= Gunny Bag; 2= Wheel Barrow; 3= 20 Litres Plastic Container; 4= Shoulder load; 5 = Any other measure (specify)							

C. INDIVIDUAL COW WEIGHT RECORD CARD						
Farmer Name:				**Enumerator:**		
	Cow No./ Name:					
Week	**1**	**3**	**5**	**7**	**9**	**REMARKS**
Date						
Heart Girth (cm)						
	Cow No./ Name:					
Week	**1**	**3**	**5**	**7**	**9**	**REMARKS**
Date						
Heart Girth (cm)						
	Cow No./ Name:					
Week	**1**	**3**	**5**	**7**	**9**	**REMARKS**
Date						
Heart Girth (cm)						
	Cow No./ Name:					
Week	**1**	**3**	**5**	**7**	**9**	**REMARKS**
Date						
Heart Girth (cm)						
	Cow No./ Name:					

D. Area Under Different Forages mentioned in B. i

	Name of forage	**Sourced on-farm (yes or no)**	**Acreage on-farm**	**Sourced off-farm (yes or no)**	**Acreage off-farm**
1					
2					
3					
4					
5					
6					
7					
8					

Give the **farmer** an opportunity to ask a **few questions**.

Record them, answer those that you can and for additional information refer the farmer to nearest Livestock Production office and/or KARLO-Mtwapa.

End of checklist
Asante sana.