SOCIO-ECONOMIC ANALYSIS OF DAIRY FEED TECHNOLOGIES PROMOTED IN THE KENYAN HIGHLANDS

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DECLARATION

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

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This dissertation has been submitted with our approval as University Supervisors.

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DEDICATION

I dedicate this dissertation to my late Mom and Dad for making me who I am, as well as my beloved wife Moonga Nkausu Sikumba and Daughter Josephine Chate Sikumba for their love, patience and dedicated partnership in the success of this project.

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Remain blessed.

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ACRONYMS

AEZ	Agro Ecological Zone
AI	Artificial Insemination
ANOVA	Analysis if variance
BOP	Balance of Payment
CBA	Cost Benefit Analysis
CBK	Central Bank of Kenya
CGIAR	Consultative Group of International Agricultural Research
CP	Crude Protein
CRC	Capital Recovery Cost
DALEO	District Agricultural and Livestock Extension Officer
DM	Dry Matter
EADD	East Africa Dairy Development Project
FAO	Food and Agricultural Organisation
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GPS	Geographic Positioning System
ILRI	International Livestock Research Institute
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KARI	Kenya Agricultural Research Institute
KSH	Kenyan Shilling
KDI	Kenya Dairy Industry
LH	Lower Highlands
MoARD	Ministry of Agriculture and Rural Development
MoALD&M	Ministry of Agriculture, Livestock Development and Marketing
MoLD	Ministry of Livestock Development
NGO	Non-Governmental Organization
OLS	Ordinary Least Squares regression
UH	Upper Highlands
UM	Upper Midlands

ABSTRACT

The cost of feed is one of the major constraints to dairy cattle production in sub-Saharan Africa. East Africa dairy development project is promoting several feed technologies for dairy cattle in order to reduce costs and increase milk production and profits. Research was conducted to identify factors that affect farmers' uptake of feed technologies, cost of feed and factors driving dairy milk yield through improved technologies and practices. There has however been no studies related to cost benefit analysis of dairy cattle feed or a measure of efficiency of dairy feed technologies in Kenyan highlands. In East Africa and the sub-Saharan region at large, research on cost benefit analysis and profitability of promoted feed technologies are not prioritized. Therefore, farmers fail to make informed decisions in fodder production due to lack of knowledge and evidence resulting in low milk production.

The study was carried out in the Kenyan highlands. The counties sampled fall under three agro ecological zones namely Upper Midlands, Upper Highlands and Lower Highlands. Three stage sampling technique was used to select farmers. The data was collected from East Africa Dairy Development supported farmers using a structured questionnaire and GPS coordinates collected for each site for spatial analysis. The farm specific profit inefficiency across the agro ecological zones was estimated using a stochastic profit frontier model and one-way analysis of variance respectively.

Famers in the lower highlands had comparative advantage of growing Napier and input costs as opposed to those in the upper highlands and upper midlands respectively. The mean level of inefficiency at farm level was 34% with variance of 5%. All the hypothesized socio economic factors that related to inefficiency were significant. The land size and gender were found to negatively influence profitability. Agro Ecological Zone, experience, scale of farming and occupation of farmers had a positive influence on profitability. Therefore in order to reduce inefficiency and increase profitability, reduction in cost of labor is critical. Since Napier had comparative advantage, farmers in the lower highlands would benefit more in adopting the fodder. Farmers in upper midlands are better off adopting fodder trees. Labor efficiencies can be achieved through use of improved mechanization or batch planting in order to reduce costs.

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Kenya has a dairy cattle population estimated at nearly 7 million; the largest dairy herd population in Africa which is more than the rest of the countries in East and Southern Africa combined (KDI, 2010). It is the third-largest milk producer in Africa, behind Sudan and Egypt (KDI, 2010). The Kenya Dairy Industry (2010) further states that, in terms of milk consumption per unit of average income, Kenya ranks only behind Mauritania and Mongolia globally among developing countries. According to ILRI (2010), on average, each Kenyan consumes, about 145 liters of milk a year, triple her Ugandan counterpart and four times the average for Sub-Saharan Africa. This shows that milk is a major source of protein to Kenyans.

The Kenya Dairy industry (2010), reported that Kenya has recently made a turn around with the annual production of milk exceeding 4 billion litres out of which 2.1 billion litres is marketed formally and informally. It further states that the volumes of milk going to processing plants have also increased to 516 million litres in 2010 as compared to 144 million litres in 2002 (a growth of 258% from 2002). The industry is a major source of livelihood to a majority of Kenyans. It contributes approximately 4% of Kenya's GDP and acts as a source of income and employment to over 1.5 million smallholder dairy farmers. In addition, the dairy industry contributes 500,000 direct jobs in milk transportation, processing and distribution and a further 750,000 in related support services (Kenya Dairy Board, 2012).

Despite this significant contribution to the national economy and household incomes, the productivity per animal in smallholder farms remains low. This is partly attributed to poor quality and quantity of feed and costly feed supplements. The other factors include lack of organized and reliable markets, low quality breeding stock, high cost of animal health and diseases control services, over reliance on rains resulting in uneven milk supply throughout the year, lack of affordable credit facilities, and high cost of artificial insemination services (KDI, 2010). Stall et al., (1997), further reported that dairy cattle farming in Kenya is constrained by poor nutrition, inappropriate cattle genotypes, livestock diseases, lack of credit to farmers and more importantly, inadequate information access to address these constraints.

In this study, the major problem is the quantity, quality and cost of feed because it directly affects milk yield and profitability. Feed is the major input cost in animal production, accounting for 65–70% of the total rearing cost (FAO, 2012). Poor nutrition of animals has been identified as the major constraint to animal production across the developing world (FAO, 2000). Due to a variety of reasons, the tropical world is largely faced with the problem of acute shortage of feed resources. With a large animal population to feed, this shortage is further compounded by lack of efforts to increase green forage production and to improve the management of degraded and unmanaged pastures. In India for example, the area under fodder production has remained static at around 4% of the total cultivable land area for the last three decades (FAO, 2012). Early in the last decade, Karanja (2003) showed that the potential for increasing dairy productivity in Kenya and especially the smallholder dairy remains great because an average yield per cow in smallholder farms is as low as 1,300 liters per year as compared to the global best practice of 4000-6000 liters.

The value of manufactured feeds increased by 14.3% per annum, partly attributed to the increased usage by livestock farmers due to drought (KNBS, 2001). In addition, the grains are also being diverted for biofuel production. The protein rich oil seed meals, e.g. soybean, groundnut and cotton seed, which are already in short supply, are also being exported indiscriminately in large quantities from east Africa to earn foreign currency (Walli, 2009). This necessitates efficient utilization of alternative feeds such as established pasture and fodder as a source of energy and proteins for dairy cattle feed.

Due to the problem of feed, the East Africa Dairy Development project (EADD) embarked on promotion of smallholder dairy feed technologies to increase milk production and profitability in the East Africa region. The East Africa Dairy Development project is a regional industry development program led by Heifer International in partnership with ILRI, TechnoServe, the

World Agroforestry Centre (ICRAF) and the African Breeders Service Total Cattle Management. The project is being implemented in Kenya, Rwanda and Uganda (EADD 2007). According to EADD (2007), the project is funded by the Bill & Melinda Gates Foundation whose goal is to help one million people translating to 179,000 families living on less than 5 acre farms to lift themselves out of poverty through more profitable production and marketing of milk.

EADD carried out a baseline survey in 2008 to identify fodder technologies that could be adopted by farmers in the Kenyan highlands. These include fodder legumes (*Calliandra, Lablab, Lucerne, Desmodium, Sesbania, Mucuna and Leucaena*), fodder Cereals (fodder maize and oats), pasture grasses (Rhodes grass and Napier grass) and feed conservation technologies (hay and silage). EADD promoted the adoption of these dairy feed technologies in order to assist farmers to reduce the cost of production and increase feed quality and quantity (EADD, 2010). However, there is inadequate information on profitability of these feed technologies. This study intends to measure the cost of growing the adopted feed technologies promoted by the ILRI EADD project and their effect on milk production in terms of profitability. More research on productivity of fodder has been carried out but there has been no research done on computing the productivity of fodder legumes in rift valley Kenya in reference to the specific agro ecological zones of the livestock keeping zones. Knowledge of the profitability and productivity of the fodder in the given areas will help farmers to choose the feed technology that gives more yield as well as be able to know the right type of inputs to use to maximize production. This would help in targeting promotion of the technologies to specific agro ecological zones. Finally knowledge on effects of spatial externalities will help farmers know the cheapest sources of inputs.

1.2. Problem statement and Justification

Most areas in the Kenyan highlands especially in three agro ecological zones namely Upper Midlands, Upper Highlands and Lower Highlands have experienced erratic and changed rainfall patterns in recent years which has affected the quantity, quality and increased cost of dairy cattle feed. The high cost of feed is one of the major challenges faced by smallholder farmers. Therefore, farmers are practicing opportunistic feeding hence not meeting the optimum feeding requirements of the dairy cows resulting in low herd productivity particularly in milk yield. This is in spite of indications that there is a potential for dairy development, and a vibrant dairy industry can help reduce the level of poverty. Therefore, in order to remain competitive, farmers need to use the least cost combination of feed production to keep production costs as low as possible. The East Africa Dairy Development (EADD) Project is promoting various feed technologies to improve milk production on small-scale dairy farms in Kenya, Uganda and Rwanda. According to Nyeko *et al.* (2004), farmers who adopt new technologies can increase financial benefits through increased biophysical productivity or through reduced input costs. Unfortunately, farmers lack information on the comparative advantage of growing the selected fodder legumes as well as their spatial profitability and productivity. Mburu *et al.* (2007) stated that measuring the cost of production is important if a farmer wants to know whether profits are generated or not. While farmers know milk prices right away, it is often difficult to assess milk production costs and profits (Bailey, 2001). The cost of milk production and milk production profitability are partly affected by factors driving farm-gate milk prices across the rural areas of Kenya (FAO, 2011a). These may be socio economic such as age of farmers, experience in farming and cultural beliefs while spatial factors include, distance to market, and access to road network and topography as well as demand and supply trends. These socio economic factors are rarely taken into account in determining the cost and benefits of feed production. The socioeconomic factors, choice of production and marketing strategies of farmers contributes to differentiated production costs which are usually low in the Kenyan highlands. As a result there has been continued interest from the public and policy makers in understanding what drives cost/benefits of various feed types so that farmers can make informed decisions based on economic profitability. This would reduce cost of production, increase milk yield and income and in the long run reduce poverty. Among the problems of low milk yield and profits due to low adoption of dairy feed technologies exacerbated by lack of information on the cost and benefits of available feed technologies.

1.2.1. Overall Objective

To enhance adoption of fodder and forage technologies promoted by East Africa Dairy Development project for dairy cattle feeding in Kenyan highlands.

1.2.2. Specific Objectives

i. To determine biomass productivity of the selected feed technologies in the three agro ecological zones in Kenyan Highlands
ii. To determine the costs of feed technologies being promoted for dairy cattle feeding among smallholder farmers in the three agro ecological zones in Kenyan highlands
iii. To determine the profitability of each promoted feed technology for dairy cattle feeding among smallholder farmers in three agro ecological zones in Kenyan highlands.
iv. To determine the farmers socio-economic characteristics that influence profitability of feed among selected feed technologies.

1.2.3. Hypothesis

i. There is no significance difference in the productivity of each promoted feed technology for dairy cattle feeding among smallholder farmers in three agro ecological zones in Kenyan highlands
ii. There is no significance difference in the cost of each promoted feed technology for dairy cattle feeding among smallholder farmers in three agro ecological zones in Kenyan highlands
iii. There is no significance difference in the profit of each promoted feed technology for dairy cattle feeding among smallholder farmers in three agro ecological zones in Kenyan highlands
iv. Socio-economic characteristics do not influence the profitability of selected feed technologies in the Kenyan highlands.

1.3. Significance of the study

The study aims at developing a decision taking support tool for dairy farmers. The support tool will consider farmers diversity in terms of spatial, climate, infrastructure and population variability in selection of the best feed technology. It will assist farmers to make informed decisions because knowledge of enterprise's profitability will enhance increased dairy production through utilization of feed that have comparative advantage in the respective agro ecological zones. This will also increase adoption of the affordable type of fodder technology for the given agro ecological zones. The utilization of scarce agricultural resources has to be efficient with the least cost combination in more economically advantageous agricultural enterprises otherwise it might result in misallocation and underutilization of scarce resources. Thus, without assessing the profitability, efficiency and comparative advantage of a given agricultural production activity one cannot adequately speak of its benefits or costs to the country.

This study will help policy makers make informed decisions and support interventions that reduce costs due to spatial externalities. Finally it will guide the dissemination strategy of the East Africa Dairy Development Project (EADD).

1.4. Scope and Limitation of the Study

The study was limited to the evaluation of fodder crops promoted by EADD. Fodder such as Acacia, Mucuna and Stylothensis were not be included in the study mainly due to the limited availability of these species in the sampled areas and insufficient resources to undertake a baseline survey before considering them. Therefore, the study is confined to six major EADD sites in Kenyan Highlands region.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Dairy cattle Farming in Kenya

The Kenya national cattle population is estimated at 3,355,407 for exotic cattle and 14,112,367 for indigenous cattle (KNBS, 2009). Kenya hosts an estimated dairy cattle population of 6,200,000, (FAO, 2007). The high number of dairy cattle found in Kenya can be attributed to several factors, including the implementation of the Swynnerton plan of 1954 supporting local farmers to take up commercial agriculture, followed by the introduction of highly subsidized artificial insemination services by the government to the livestock sector in the 1960's and 1970's. In 1968, AI was adapted as a key and priority government activity to improve livestock productivity among indigenous farmers (Philipsson *et al,* 1988; Israelsson and Oscarsson, 1994).

Paterson, *et al.* (1998) reported that the Kenyan dairy population is composed of 80% Friesians, Ayrshires, Guernseys, Jerseys and their crosses with local Zebus which are found on small-scale farms (approximately 1–2 ha) in the high potential areas of Western, Central and Coastal Kenya, where they produce about 80% of the marketed milk. The author further states that production systems are mainly intensive in nature largely based on zero and semi zero grazing. Most small-scale farmers practice zero-grazing where animals are totally confined in sheds and cut-feed is carried to them. In semi zero-grazing systems, often used by larger scale farmers, cows graze on both natural and improved pastures by day and are confined at night, when they are offered a variety of feeds. While animal health can often be important, nutrition, particularly during the dry seasons, is commonly seen as the major limitation to dairy production. Surveys conducted in five central districts and three coastal districts of the country (NDDP, 1994) showed that the mean daily availability of dry matter (DM) from Napier grass (*Pennisetum purpureum*), the main fodder source, was 8.8 and 9.6 kg/head/day. This compares poorly with the estimated daily DM requirement of the common dairy breeds of 14–17 kg/head/day (NDDP, 1992), suggesting a large feed deficit.

The deficit limits the productivity of the large cattle population due to both quantity and quality of feed particularly during the dry seasons. This problem has led to massive research where new feed technologies have expanded on the use of herbaceous legumes and more recently fodder trees for animal production, but farmer adoption of this technology has been relatively low. However, the few farmers who have adopted these technologies have reported increased milk yield (EADD, 2010). In Kenya, the main reason for not growing fodder relates to lack of technical know-how and awareness (along with unavailability of planting materials) (EADD, 2010).

2.2. Fodder Adoption and Production in Kenya

Feeding constitutes the largest portion of the costs of milk production in market-oriented dairy farming (Muriuki, 2011). A review of various small holder development project publications, Muriuki (2011) observed that generally, dairy animals in Kenya are underfed, resulting in low milk yields. The average annual milk production is about 1 600 kg per local lactating cow and that the officially recorded average for the Friesian breed is about 4 200 kg over 305 days of lactation (Muriuki, 2011). It is stated that the low average milk yields are attributed to poor or underfeeding of lactating cows, and poor feed quality.

Results from the EADD (2010) baseline survey show that livestock feeds in Kenya account for 60 – 80% of the total livestock production costs. To reduce feeding costs, use of alternative sources of energy and protein, and crop residues in animal feeds is recommended (Republic of Kenya, 2007). Several forage production and utilization technologies have been promoted by EADD proggramme. They include established pasture, fodder cereals, fodder grasses, fodder legumes and feed conservation technologies (hay and silage).

In Kenya, Napier grass is the most important forage among smallholders cultivated by 49% of livestock farmers (EADD, 2010). Maize stover was also reported as an important fodder being fed on 50% of the surveyed livestock keepers (FAO, 2011b). Cut grass is commonly practiced by 13% of farmers in Kenya; reflecting the importance of 'cut and carry' feeding systems (Franzel et al., 2003).

A very small percentage of dairy farmers in Kenya have adopted fodder trees and legumes. The most common fodder trees are *Leucaena leucocephala* and *Calliandra calothyrsus* while the most common herbaceous legume include *Desmodium uncinatum* and *D. intortum, Lablab purpureus* (EADD, 2010). This agrees with past research by Omore *et al.* (1999) and Peters and Lascano (2003) who observed that in developing countries grasses were being adopted more quickly and more strongly than legumes. Legumes were regarded as less resilient than grasses under cutting or grazing, benefits were largely long-term in nature, and grass-legume systems were more complex to manage. They further reported that the trend is similar, in East Africa, where the rapid adoption of grasses, such as napier grass in cut-and-carry systems, contrasted with the lack of adoption of herbaceous legumes. Therefore, besides fodder adoption to increase milk yield, the knowledge on profitability of the respective fodder technologies is important for farmers to be able to know the costs and benefits of available feed technologies.

2.3. Productivity of the adopted fodder/forage

As stated earlier from reports by Stall et al., (1997), it is apparent that milk production in Kenya is limited by both the quantity and quality of feed available. Therefore, any strategies aiming at increasing milk production must address both feed quantity and quality issues. In this regard, the contribution of established pasture, fodder shrubs and legumes to milk yield and profitability are discussed below.

Napier grass is one of the feed technologies that has been adopted and grown in most parts of Kenya, where it is associated with smallholder dairy production systems. The grass remains the most important fodder crop for land constrained livestock producers due to its high yield of up to 40 tonnes dry matter per ha, rapid regeneration and tolerance to drought. In Western Province, over 22,525 ha of Napier grass is grown to feed a livestock population of approximately 1.8 million cattle, 250,000 goats and 120,000 sheep (District Annual Reports, 2004).

Table 1: Productivity of Selected fodder

Fodder Type	Yield tones /DM/Hectare	Protein content (%)	Data Source
Desmodium uncinatum	17	15	ILRI, 2010
Lablab purpureus	30	12	ILRI, 2010
Leucaena leucocephala	30	22	ILRI, 2010
Oats	5-10	8-12	Lukuyu *et al.* (2007)
Rhodes grass	8	n/a	Lukuyu *et al.* (2007)

Research has been carried out to quantify the productivity of fodder in Kenya. See appendix 1 for table on productivity of selected fodder from results by EADD Kenya. EADD project did a proximate analysis to quantify the nutritive value of promoted fodder in East Africa and this included grass, cereals, legumes and fodder trees. These are reported in appendix 2.

2.4. Contribution of fodder to dairy cattle milk yield

Roothaert and Paterson (1997) compared the nutritive value of several common fodder tree species such as *Leucaena leucocephala*, *Calliandra calothyrsus* and *Sesbania sesban*. Assessing calliandra as a substitute for dairy meal, the trials found that 1 kg of dry calliandra (or 3 kg of fresh) had about the same amount of digestible protein as 1 kg of dairy meal, and both increased milk production by roughly 0.60–0.75 kg under farm conditions (Roothaert *et al.* 2003; Paterson *et al.*1998). Kabirizi (2009) found that adding 1 kg of calliandra daily to a diet of napier, lablab and homemade concentrate increased the daily milk production of a cow by 0.7 litres.

While feeding trials have found that one kilogram of calliandra increases milk production by 0.6–0.8 kilograms, a new survey of farmers' perceptions in Kenya found the effect to be about half as large after controlling for the effects of breeds, season and other feeds (World Agroforestry Centre, 2009). If compared with commercially-available concentrates, 1 kg of dry calliandra fodder would contain the same quantity of nitrogen as 1.5 kg of dairy meal with 16% CP. Allowing for a digestibility of the concentrate of some 80% compared with an estimated

60% for the fresh tree fodder, one kilogram of calliandra DM should have the same effect when used as a protein supplement as 1.1 kg of dairy meal (Paterson *et al*., 1998).

In Tanzania, 30 grazing crossbred dairy cattle were selected from farmers' herds and randomly placed in five groups with different supplement feeds (Kakengi *et al*., 2001). The experiment showed that 2.6 kg of leucaena leaf meal with 1.8 kg of cottonseed husks gave similar milk yields as a manufactured 1.8 kg cottonseed cake.

According to Muyekho et al. (2005), a cow in mid lactation period will produce on average 5-7 kg milk per day on grass alone and 7-10 kg milk per day on grass/legume mixture. To achieve the milk quantities mentioned, an average dairy cow requires 70 kg or 7 headloads of fresh unchopped napier grass per day to produce 7 kg of milk or 9-12 kg milk per day when fed on napier/legume mixture. Muyekho et al. (2005) further states that an average dairy cow needs 70-80 kg of fresh oats to produce 12 kg of milk per day and 3-6kg of green Desmodium herbage can be used to replace 1-2 kg of dairy meal.

Studies in Embu suggest that fodder shrubs can replace commercial concentrates within the normal range of feeding of commercial concentrates (2.0–4.0 kg per day) at a ratio of 3.0 kg of fresh material (0.8–1.0 kg dry matter equivalent) to 1.0 kg dairy meal with 16% crude protein (Paterson *et al.* 1999).

The studies above show that feed technologies have a great impact on milk yield but there is no research that has been carried out to quantify the comparative advantage of growing the selected feed technologies in Kenyan highlands. Therefore, there is need to carry out research in this area in order for farmers to have access to information that will help them to wisely choose wisely the type of technology suitable for a given zone.

2.5. Dairy Development Policies

The Kenyan dairy industry has grown impressively with credit attributed to the supportive government policies, especially in the period after independence, which encouraged small-scale farmer's participation in the industry. The liberalisation of the dairy industry in 1992 in line with the economy wide reforms brought about reduction in the public sector expenditure, corrected the worsening balance of payment (BOP) deficit and minimised economic inefficiency so as to spur economic growth. With liberalisation, milk and input prices were decontrolled (Karanja, 2003).

The government introduced cost sharing with farmers which progressed into full cost recovery and privatisation in provision of the previously subsidized AI, dipping and veterinary services. Private processors were allowed into the milk market to compete with the KCC which previously had a monopoly in milk processing and marketing. Informal milk traders have also gained a greater share of the market accounting for about 70% of the marketed milk (Kiriro, 2001). Within the context of liberalisation, the government's policy objective is attainment of self-sufficiency in milk and dairy products through efficient increase in production by farmers and existence of competitive, efficient and self-sustaining processing and marketing systems (Karanja, 2003).

The dairy industry faces numerous challenges. First, the liberalisation was associated with rising prices of input and services, making them less affordable by farmers. There was also a collapse of some livestock support services to farmers. For instance, the artificial insemination services are currently inadequate and only about 20% of high grade cows are served with AI, Veterinary and dipping services, which used to be provided by the government. These services are no longer as easily available although the private sector is slowly beginning to provide them (Omiti and Muma, 2000). Milk marketing has also been hampered by dilapidated infrastructure, especially poor rural roads, collapsed co-operatives and other marketing facilities. Credit for dairy farming especially to the small-scale sector is often unavailable, and when available, it is considered rather costly.

2.6. Social and Dynamic Factors that influence Profit and efficiency of feed

There is no research that has been done to determine the social economic factors that influence cost, efficiency and profitability of feed. However, such studies have been done in food crops. Alin and Flinn (1989) carried out a research on profit efficiency among basmati rice producers in Pakistan Punjab and he found out that farm household education, non-agricultural employment, credit constraint were factors related to profit. Studies by Guthiga et al (2007) showed that land size, area under cultivation and type of draft power used were significant while years of schooling, experience in farming, family size and age of household head were not significant. Other research by Oladeebo and Oluweranti (2012) in Nigeria also hypothesised that years of education, membership to cooperative, household size, credit amount used could influence profit and inefficiency. These could help develop a model on factors that could influence feed profitability and inefficiency in the dairy cattle feed.

2.7. Empirical studies on cost benefit analysis

In the absence of an effective market for goods and services some mechanism is needed to guide public resource allocation towards maximizing societal resources. This recognizes that there is an opportunity cost to every decision for example made by a farmer to allocate resources to one enterprise (feed technology) over another. Opportunity cost is the 'benefits forgone in the next best use of resources' (Jalaludin, 2009). Cost of using family members for labor and costs of gifts and communal equipment are opportunity costs which are usually ignored. One way to minimize opportunity cost and maximize milk yield is to apply cost benefit analysis (CBA) to farm enterprises, where the objective is to maximize the milk yield of the cattle. CBA provides a means to operationalize the opportunity cost principle.

Comparative advantage analysis facilitates determination of the economic, as opposed to financial, profitability of an enterprise or technology. It allows the estimation of benefits independent of all market distortions caused by interventions in the market (Staal and Shapiro, 1994). In other words, it permits comparison of real or economic costs of production to other price references in order to determine what the activity's profitability would be in the absence of those technologies which cause local prices to be different from other prices.

A CBA is undertaken for each alternative and the results are presented as net present values (NPVs). The alternative that has the highest net benefit is the most efficient and preferred.

In order to estimate the costs and benefits of different fodder technologies the major terminologies have to be understood.

A cost according to Jalaludin (2009) is measured by the opportunity forgone to derive benefits by deploying those resources in the next best alternative. This is the 'opportunity cost' of resource allocation. In a fully functional market, price would reflect the opportunity cost of a good or service. In practice, the evaluator often has to find a proxy or 'shadow' price that approximates opportunity cost. Using a welfarist framework, a benefit is anything that produces 'utility' for the consumer and societal benefits are calculated by aggregating individual net benefits across a population (Jalaludin et al, 2009).

In the past, economic evaluation of various technologies to determine output and sometimes financial/ economic benefits accruing to farmers have been undertaken using on-farm trials (Muyekho *et al,* 2003). This often leads to biased results as production is done under controlled conditions and the assumption of a ready market is made which is usually not the case (Franzel, 2004). The selection of assumptions and other inputs used to estimate benefits and costs leads to inaccurate estimates. An accurate estimate of the economic value of non-market goods and services is a key component in a Cost Benefit Analysis, and such valuation relies heavily on contingent valuation methods. Research by Kiratikarbkul (2010), Mburu, et al. (2007), van Schaik, et al. (1996) and Hanley (1993) on cost benefit analysis failed to quantify non marketed benefits in the cost benefit analysis. They made two assumptions that did not explicitly consider the equity implications of a policy or decision, and that the overall behavior of an option is the sum of individual preferences (or utilities).This study employed financial analysis which was based on the costs and returns that farmers get for the marketed feed. Non-marketed feed technologies were taken into account.

CHAPTER THREE

3. METHODOLOGY

3.1. Study Area

The study was carried out in Rift Valley province in the Kenyan highlands. The counties sampled fall under three agro ecological zones namely Upper Midlands (Kabiyet and Siongiroi), Upper Highlands (Olkalou) and Lower Highlands (Longisa, Liten and Metkei) (figure 1). The Kenya highlands comprise areas with altitude 1200-2550 meters and annual mean temperatures of 13.4^{0}C to 21.9^{0}C. The rainfall is bimodal varying from 600-1200 mm per year depending on location and altitude. Fertile soils in these areas have good potential for biomass production, are intensively cultivated and food is cropped once or twice a year (Jaetzold and Schmidt, 1983). Dairy cattle farming in the sampled counties include the extensive, semi-intensive and intensive grazing production systems. The study was conducted from January 2012 to August 2012.

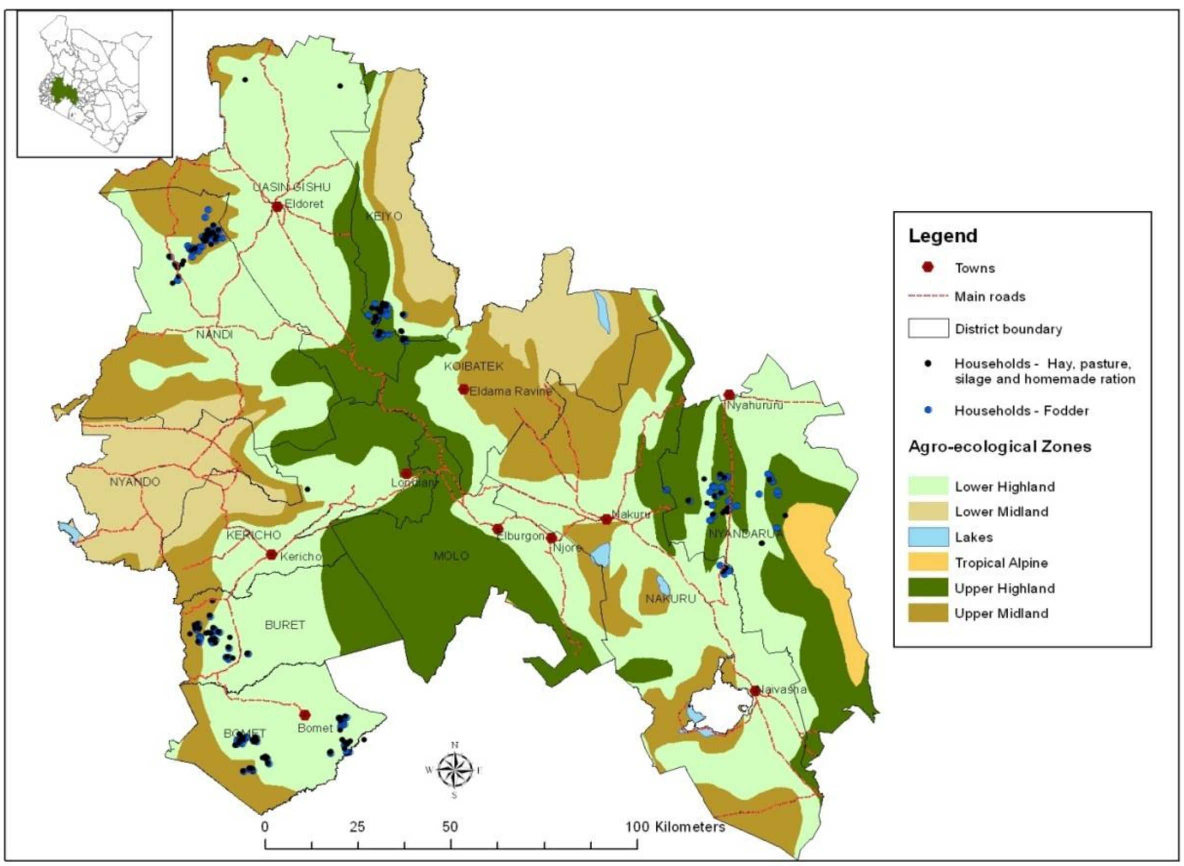

Figure 1: Study Area (*source own construct*)

3.2. Research Design

The study used ex-post facto design and involved a survey of farmers who have adopted the feed technologies promoted by EADD. An adopter for fodder trees/shrubs was defined as a farmer who had planted at least 50 shrubs, kept records and had harvested in the previous year. Herbaceous Fodder or fodder cereals adopters were farmers who had planted fodder on at least half an acre, kept records and had harvested in the previous year. A purposive, cluster multi stage sampling design was adopted for this study.

3.2.1. Stage One: Sampling of AEZ's

Three agro ecological zones were purposively sampled based on coverage showing the agro-ecological zones of Kenya based on temperature belts (maximum temperature limits within which the main crops of Kenya can flourish) and the main zones (probability of meeting the temperature and water requirements of the leading crops i.e. the climatic yield potential). Its aim is to provide the frame-work for ecological land-use potential. This coverage does not include information on the non-cultivated (pastoralist) areas. There is, however a grid layer Kenya_LGP_AEZ, based on length of growing period done by FAO (2012) which has information on the whole country. This method identified three agro ecological zones suitable for feed production (table 2).

Table 2: Selected Agro Ecological Zones and Sites in Kenya highlands

AGRO ECOLOGICAL ZONE	AREA (SITE/HUB)	Site Coordinates	
		X Coordinates	Y Coordinates
Upper Midlands	Kabiyet	35.076707	0.419150
Upper Midlands	Siongiroi	35.230107	-0.897562
Upper Highlands	Ol Kalou	36.333615	-0.322274
Lower Highlands	Liten	35.131591	-0.565327
Lower Highlands	Metkei	35.382442	0.005264
Lower Highland	Longisa	35.377868	-0.831094

3.2.2. Stage Two: Sampling of sites

The sites were identified in each AEZ by purposive sampling based on feed recommendation domain maps as shown in Figure 2 for Napier grass as an example. The objective was to select areas where the selected feed types for the study match the agro ecological conditions. The feed dissemination facilitators for respective sites were then asked to confirm the maps.

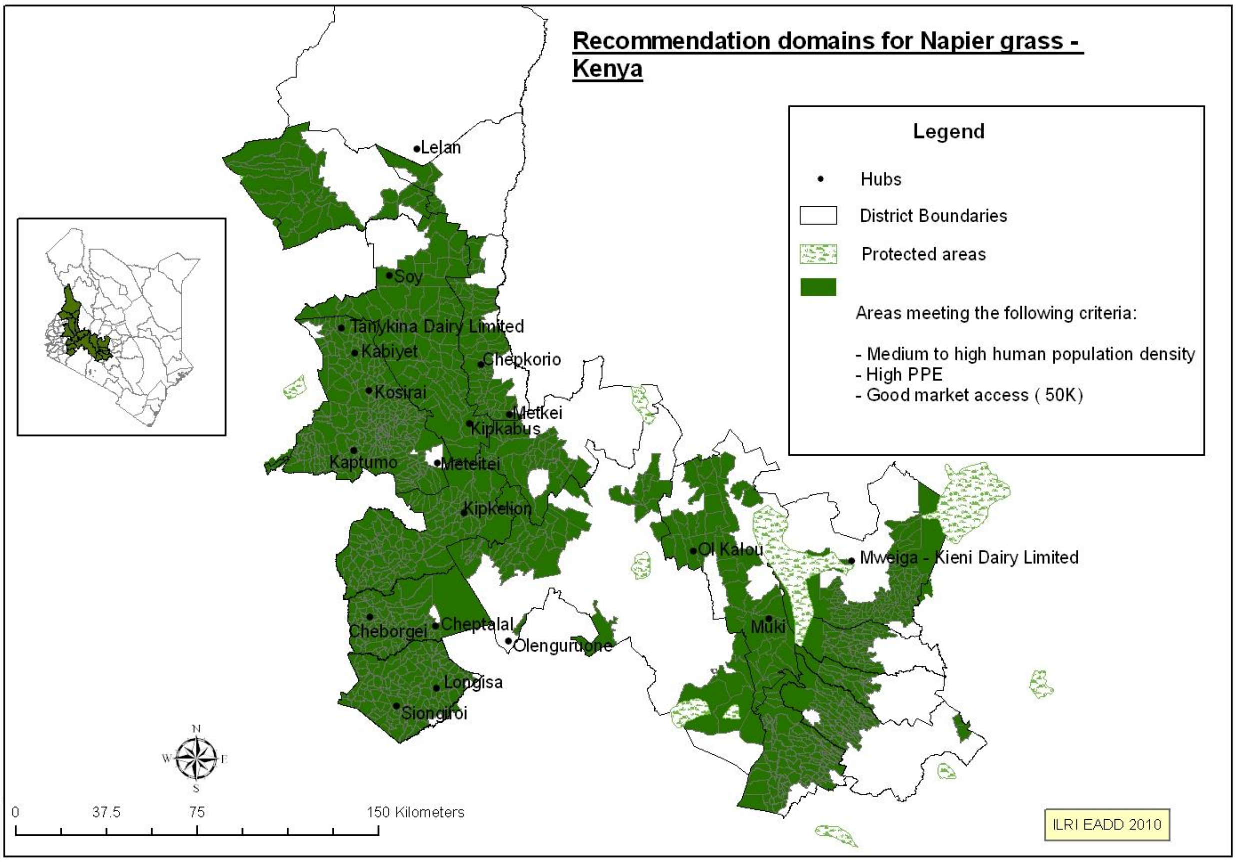

Figure 2: Napier grass recommendation domain in Kenya

A total of six sites (Clusters or dairy management groups) (table 1), were selected according to the feed recommendation domains

3.2.3. Stage Three: Sampling of Farms/households

The final stage was to identify farmers. A clustered random sample of adopters was drawn from the 6 sites (hubs) in the Kenya highlands where EADD had promoted the specified technologies between 2008 and 2011. The rationale for surveying only adopters was that these farmers were willing and able to give information, were experienced, had financial records and were likely to have demonstrated the benefits of the technologies.

3.3. Sample size

Originally the target sample size was 360 adopters consisting of 6 farmers per technology per scale of farming in each site. Unfortunately it was not possible to find a large enough sample using the stipulated criterion. The sample size was derived from the findings of Singleton *et al.,* (1988), who recommend a minimum of 30 cases for statistical data analysis but argue that for most social research a minimum of 100 cases is preferable.

A total of 163 adopters were interviewed. This included 57 farmers for Napier grass, 54 farmers for fodder cereals and 52 Fodder legumes (trees and herbaceous) (table 2). In cases of non-responses or insufficient respondents identified; a different farmer was randomly selected in the same locality and hub respectively and substituted. A smaller sample size was derived due to lack of adequate number of adopters in the study area who fitted the sampling protocol.

Table 3: Sample size for fodder and Conservation Pasture

Fodder Type	Agro Ecological Zones			
	Upper Highlands	Upper Midlands	Lower Highlands	Total
Napier Grass	9	19	29	**57**
Fodder Cereals (Maize & Oats)	16	18	20	**54**
Fodder Legumes	12	17	23	**52**
Total	**37**	**54**	**72**	**163**

3.4. Data collection and Variable Measurements

Collection of data was done through face to face interview by enumerators who were trained on the questionnaire (appendix 3). Data on production cost, yield and revenue were collected and analyzed.

Data was collected using personal digital assistant (PDA)'s. Collection of data was done through face to face interview by administering a structured questionnaire which was entered directly into the PDAs. Data on production cost, areas under fodder, yield, revenue and GPS coordinates (using a GPS device) was collected and cleaned for analysia. Database was created using the Census and Survey Processing System (CsPro).

Information on costs and revenue for both marketed and non-marketed feeds were obtained from the farmers.

Calculation of Travel time Distance

Three travel time layers were calculated using a friction layer and georeferenced sources of inputs sources. This included travel time to hub, travel time to nearest urban centers with populations above 100,000 people and travel time to nearest medium urban center with population between 20,000 and 100,000 people. Ecledian distance was also calculated from the farm to the nearest major roads. These four indicators (nearest hub, nearest urban centers, nearest medium urban Centre and nearest main road) were extracted from each site as variable's in order to test if they contribute to the feed cost.

Fodder yield computation

The yield in tonnes per acre was calculated as the amount of fodder harvested per acre in tonnes. This was used to calculate the revenue, gross margins and productivity of the fodder in the respective sites and AEZ's.

Total Revenue of fodder

This was estimated by multiplying the average market price of feed in the respective site and the total yield tonnes per acre produced (Equation 2.). Where farmers did not have information on the average cost of feed technologies, information, on feed cost was sourced from extension staff in the area and literature. The total cost of feed was estimated from aggregating the cost of producing the fodder which included the cost of planting material, labor, fertilizer and manure, pesticides, herbicides and fungicides and transport (Equation 3.).

Gross Margins of fodder

Analysis of difference in net income between different methods of approach is very important in finding the best method for application. In this study, a financial analysis (using gross margins) was used for comparing the costs and benefits between different AEZ's. The main steps in this analysis were:

- Identifying the costs of each alternative.
- Evaluating the costs of each alternative.
- Comparing the costs and benefits of the feed technologies between the three agro ecological zones.

In financial analysis, benefits are valued as generated profit which was computed and the value of feed produced was calculated using the following formulae as feed profit (KES /acre). The formula characterized as follows:

Feed profit= [Feed Revenue (KES /acre) - Feed cost (KES /acre)]………………………………………….. (1).

Where: Feed Revenue = [Feed price (KES /acre) X Feed Quantity (acre)]……………………………... (2).

Where: Feed cost (KES /acre) = [Cost of Labor + other variable cost]………………………………… (3).

3.5. Analytical Approaches

Analysis of Variance (ANOVA) is a statistical technique used to investigate and model the relationship between a response variable and one or more independent variables (factors). It is used to determine if more than two population means are equal. The technique uses the F-distribution (probability distribution) function and information about the variances of each (within) and grouping of populations (between) to help decide if variability between and within each populations are significantly different. Anova acts the same as a t test but prevents needing to do multiple t tests. When there is only one way to classify the populations of interest we use one-way ANOVA to analyze the data. It consists of two variables, one categorical and the other Quantitative. The main Question is whether the (means of) the quantitative variables depend on which group (given by categorical variable) the individual. In cases where a categorical variable has only 2 values, a two sample t-test is appropriate while ANOVA allows for means of 3 or more groups to be compared. A t-test is no appropriate for more than 2 variables because it increases the error term. One-way ANOVA analyses the effect of only one (categorical) variable. When using the t-test to assess whether two population means differ, we compute a t-statistic and its p-value to assess the statistical significance of the difference in the sample means. When comparing several means, we use ANOVA, and instead of t-statistic, ANOVA uses F-statistic and its p-value to assess the null hypothesis that all the several are equal. A one-way analysis of variance is a statistical methodology for comparing several population means where there is only one predictor variable. In ANOVA, when the null hypothesis is rejected, multiple comparison or post hoc analysis methods to assess which pairs of means differ are used. Multiple comparison procedures are higher-level statistical processes that are used to determine whether the means are different for all possible pairs of the factors. These multiple comparisons are used as a follow-up when significant differences are detected in population means. Examples of multiple comparisons or post hoc analysis are Scheff, Bonfenonni and Sidak methods.

3.5.1. Analysis of the productivity of Fodder

As discussed earlier in the initial analysis, the productivity of fodder tonnes per acre (yield per acre) was calculated as the amount of fodder harvested per acre which was expressed to dry matter content. The yield was equated to dry matter content (table 4). Literature from EADD (2010) and table in appendix 1 helped to come up with the conversion. The productivity of the land in dry matter content was calculated and compared with the expected biomass in dry matter content using the table in appendix 1 and available literature and the amount of fodder harvested per land cultivated. The productivity of fodder in tonnes per acre was also used to compare which fodder performed best across the three agro ecological zones for the EADD promoted fodder technologies.

Table 4: Conversion of Yield to Dry matter

Fodder Type	Conversion Factor from Kg/acre to kg DM/acre
Napier grass	0.24 KG DM/Acre
Fodder Maize	0.25 KG DM/Acre
Fodder Oats	0.33 KG DM/Acre
Fodder Trees	0.28 KG DM/Acre
Fodder Legumes	0.25 29 DM/Acre

Source, (EADD, 2010)

After computing the productivity of fodder in each AEZ, a one-way analysis of variance was used to find out whether the yields of each fodder type were significantly different for the three regions. A one way ANOVA was chosen because there were only dummy variables in the model representing a single qualitative variable. All the 5 fodder types were tested for the hypothesis below.

H0: AEZ1 = AEZ2 = AEZ3

Where;

AEZ1 = fodder yield in upper Highlands

AEZ2 = fodder yield in upper Midlands

AEZ3= fodder yield in Lower Highlands

3.5.2. Analysis of total variable costs of growing each promoted feed technology

The variable costs of growing each technology were equated by calculating the variable costs of production. This involved all incurred costs and shadow costs such as family Labour and gifts. The costs for family labor and gifts that are directly used in producing the fodder were equated to market prices with the help of local extension officers. The variable cost used to estimate the costs of production are tabulated in appendix 4. All the fixed costs were not included in the estimates because they are insignificant in influencing feed costs and do not affect the optimal combination of the variable inputs. They were also excluded because they are usually used in other farm enterprises and their input is usually insignificant (e.g. hand hoes or panga).

3.5.3. Cost/benefit of each promoted feed technology in the AEZ's

After computing the profitability for the three survey sites, a one-way analysis of variance was used to find out whether the costs and profits were significantly different for the three regions. A one way ANOVA was chosen because there were only dummy variables in the model representing a single qualitative variable. All the 5 fodder types were tested for the hypothesis below.

H0: AEZ1 = AEZ2 = AEZ3

Where;

AEZ1 = Costs/profits in upper Highlands

AEZ2 = Costs/profits in upper Midlands

AEZ3= Costs/profits in Lower Highlands

3.6. Model specification for inefficiency and profit determinants

When the profit and cost functions violate normality assumptions a stochastic profit function model is used to specify the model to estimate the farmer's spatial and socio-economic characteristics that influence efficiency of the sampled farming feed technologies. The hypothesis that spatial, socio-economic and dynamic characteristics do not influence efficiency of production of the selected feed technologies in the Kenyan highlands was tested against the alternative that at least one of the spatial and socio-economic characteristics influence efficiency in production of the selected feed technologies in the Kenyan highlands.

While several methods could be used to estimate the frontier (Fried et. al., 1993), stochastic profit frontier models and stochastic cost frontier models are increasingly used, as they are theoretically derivable from duality theory, are intuitively appealing, and can be estimated in a straightforward manner with flexible functional forms using maximum likelihood estimation. Nonetheless, the model's parameters can be consistently estimated by ordinary least squares (*OLS*) since *OLS* is robust to non-normality. Thus, the technical parameters of the production function, with the exception of the constant term, can be estimated consistently, if not efficiently by *OLS* (Greene, 2005). The stochastic profit function models to estimate the farms specific efficiency was chosen as opposed to the production function because according to Yotopoulos *et al*. (1970), the production function approach may not be appropriate because farmers in the sampled areas face different prices and have different factor endowments. The profit function approach combines the concept of technical and allocative efficiency in the relationship and any error in the production decision is assumed to be translated into lower profits or revenue for the producer.

The model equation was specified as follows;

$$\ln \pi' = \alpha_0 + \sum_{i=1}^{3} \alpha_i \ln p_i + \tfrac{1}{2} \sum_{i=1}^{3} \sum_{k=1}^{3} r_{ik} \ln p_i \ln p_k + \sum_{i=1}^{3} \sum_{l=1}^{2} \phi_{il} \ln p_i \ln z_l + \sum_{l=1}^{2} \beta_l \ln z_l +$$

$$\tfrac{1}{2} \sum_{l=1}^{2} \sum_{q=1}^{2} \varphi_{lq} \ln z_l \ln z_q + \nu - \mu \quad \text{...(4)}$$

where:

$$\mu = \delta_0 + \sum_{d=1}^{6} \delta_d w_d + \vartheta \text{ ....(5)}$$

$r_{ik} = r_{ki}$ for all k, i

π' restricted normalized profit computed for jth feed defined as gross revenue less variable costs divided by feed specific fodder price p_f.

ln = natural log

p_i = price of variable inputs normalized by price of output where (for i =1, and 2) so that:

p_1 = the cost of hired labor normalized by price of fodder (p_y)

p_2 = the cost of "other inputs" normalized by price of fodder (p_y)

z_l = the quantity of fixed input (ι = 1)

where :

z_1 = land under fodder (hectares under fodder) for each farm j

μ = inefficiency effects

ϑ = truncated random variable

δ_0 = constant in equation 5

ω_d = variables explaining inefficiency effects and are defined as follows:

ω_1 = other Occupation (non-farming income source

ω_2 = Land size of farm owned acres

ω_3 = gender

ω_4	=	experience
ω_5	=	Scale of farming (1= small, 2= medium. see appendix for definition)
ω_6	=	Agro Ecological Zone (AEZ)

α_0, α_i , r_{ik} $\emptyset_{il}$, β_l, , ϕ_{lq}, δ_0 and δ_d, are the parameters to be estimated.

3.7. Definition of Variables and Estimation of Profit Frontier Function

Table 5 shows the list of variables included in profit frontier function (model 4). The variables were picked based on the literature earlier reviewed. Labor is included in the model because it is one of the primary factors of production. It has been collapsed into total labour (cost of hired labor and family labour (p_1)) as done by other studies by aggregating all the labor and normalizing it with the output prices (Lau and Yotopoulos, 1971; Abdulai and Huffman, 2000, Akinwumi, and Djato, 1996 and 1997; Sharma *et al.,* 1999). The other inputs (p_2) include Fertilizer, pesticides and transport costs.

Land (z_1) is defined as net area covered by fodder and was treated as fixed input in line with (Lau and Yotopoulos, 1971). The authors argued that given the periodic nature of agricultural technology, it was reasonable to treat land as a fixed factor in the short run and hypothesized to effect profit efficient positively.

Table 5: Definition of variables

Variable	*Definition and measurement*
Dependent variable:	
Profit	This is the gross revenue less the total variable cost. It a continuous quantitative variable measured in Kenyan shillings
Independent variables:	
Years of Farming Experience	This is the number of years the farmer has been engaged in fodder production. The years are expressed as a quantitative continuous variable (years)
Gender	Sex of household head = 1 if the household head is female and 0 otherwise
Other Occupation of household head	This is the other income generating activities of farmers besides farming. It was measured on a nominal scale *(1=Primary, 2=Secondary, 3=University)*
Scale of Farming	Scale of farming is defined in appendix 4. (1=small, 2=Large)
Land under fodder	This is the total amount of land that is occupied by fodder. It's a continuous quantitative variable, Measured in hectares.

3.8. Prior expectations

Female headed households are often a focus of small scale dairy cattle projects (e.g. stall fed heifer projects). However women face specific constraints in terms of access and control of assets and income. It is therefore expected that gender will have a positive effect on inefficiency. Years of farming experience have shown that past positive gains form dairy management would create knowledge on cost reduction and efficiency hence the expected sign would be negative. Other Occupation of farmer as in other income generating activities could influence information, skills and alternatives of feed cost reduction strategies. The expected sign would be positive.

As land becomes more limiting the necessity for intensive management emerges depending on scale of farming (appendix 5).. Therefore, the expected sign for land size and land under fodder would be positive. It was hypothesized that with the larger land size efficiency decreases; also the distance to nearest urban centers would increase the cost of production

3.9. Analysis of socio-economic characteristics that influence profitability and efficiency

Stochastic Frontier model was used to explore factors that influence inefficiency and profitability of the feed technologies. Technical Efficiency according to Farrell (2012), is the ability to succeed in producing as large as possible an output from a given set of inputs provided that all inputs and outputs are measured correctly. Inefficiency is the opposite of technical efficiency where one fails to produce as large as possible an output from given set of inputs.

CHAPTER FOUR

4.0. RESULTS AND DISCUSSIONS

The main objective of this chapter is to answer the four objectives of this study which are (i) to determine the productivity in terms of biomass of the promoted feed technologies, (ii) to determine the costs of each promoted feed technology for dairy cattle among smallholder farmers, (iii) to determine the farmers socio-economic characteristics that influence efficiency in the production of the selected feed technologies and (iv) finally to evaluate the cost/benefit of each promoted feed technology for dairy cattle feeding among smallholder farmers in the three agro ecological zones in Kenyan highlands.

4.1. Farmer and Farm Characteristics

The farmer characteristics varied across the Agro Ecological Zones (table 6). On average farmers in the upper highlands were older (56 years) than the rest. Farmers in the upper highlands were also on average more experienced due to higher years in farming than the upper midlands and lower highlands by an average of 5.9 and 4.6 respectively. The age of farmers and farming experience shows a significant weak positive relationship (0.37, $p < 0.0000$). This means that farmers who are old were more likely to be more experienced than young farmers. Therefore, farmers in the upper highlands were more proficient in the methods of production and optimal allocation of resources is expected to be achieved. The more experienced farmers are in feed production, the more they would have higher profits and lower inefficiency. The upper highlands also had the highest average land size (10.90 acres), area under fodder (1.1 acres), Travel Time Distance to nearest Large Urban Centre (38.98 min) and Average Travel Time Distance to hub (22.69min). Average Travel Time Distance to nearest medium Urban Centre (33.06min) was longer in the upper midlands. The distance to the main road was long in the lower midlands (8.39metres). This means that farmers in the upper midlands could incur higher transport costs than the rest. Lower highlands are on average far from the main road.

Table 6: Farmer Characteristics by AEZ

Parameters		Agro Ecological Zones		
		Upper Highlands	Upper Midlands	Lower Highlands
Average Age of Household Head Age		56	43	49
Years in Farming Experience		10.2	4.3	5.6
Land Size (Acres)		10.90	5.54	5.89
Average area under Fodder (Acres)		1.10	0.68	0.47
Average Travel Time Distance to nearest Large Urban Centre (min)		38.98	34.26	30.58
Average Travel Time Distance to nearest medium Urban Centre (min)		15.73	33.06	24.72
Average Travel Time Distance to hub (min)		22.70	11.67	14.95
Average Distance to nearest main road (meters)		4.55E3	1.02E4	8.40E3
Gender of Household Head %	Male	94%	96%	88.5%
	Female	6%	4%	11.5%
Occupation of household Head %	Farmer	75.61%	64.94%	60.00%
	Employee in Private Sector	0%	5.19%	4.71%
	Business Person	0%	11.69%	1.18%
	Retired	7.32%	1.30%	10.59%
	Civil Servant	9.76%	15.58%	22.35%
	Other	7.32%	1.30%	1.18%
Farming Scale	Small Scale	59%	66%	61%
	Medium Scale	41%	34%	39%

The average percentage of males in the three AEZ's was more than 80% meaning that farming in the Kenyan highlands is male dominated. The lower highlands showed a slight high percentage of females (11.5%) compared to the rest. According to information from informal discussions during data collection, there are more females in lower highlands due to cultural background that forces women to take care of animals especially dairy cattle. The main reason why there could be more male farmers in the area under study could be due to the cultural background of the Kalenjin and Kikuyu which have male dominated households. From the focus group discussion it was established that even if a woman is the one who is actively involved in farming, they prefer to claim that the man is the one in charge. The most common non farming activity was found to be employment in private sector and in most cases dairy production was found to be a secondary occupation. Though farmers were involved in other non-farming activities, farming was the dominant income generating activity. According to the results, most farmers are small scale farmers in the Kenyan highlands. This could entail more intensification and efficiency.

4.2. Productivity of Fodder in the AEZ

The productivity of Napier grass and fodder trees (Calliandra and Leucerne) is high in the lower highlands (Figure 3). This may be due to the favourable production factors found in the zone that favours production of Napier and fodder trees (Jaezoldt 2001). Napier grass requires high and well-distributed rainfall (more than 1000 mm per annum) although it can tolerate a moderate dry season (3-4 months) because of its deep root system. At higher altitudes (above 2100 m), growth is slowed by lower temperatures; optimal temperatures for growth are in the range 25 to 40^{o} C with high rainfall (Russell & Webb, 1976). Therefore the lower highlands provide such conditions hence the high productivity. The lower highlands also have well drained soils, and napier establishes well in clay or sandy loam and deep, fertile loam soils produce best growth and yields. The upper midland is more productive in fodder legumes compared to the rest of the AEZ's. The large yields of fodder cereals in the lower highlands can be attributed to the cultural back ground were ugali (maize meal) is the staple food.

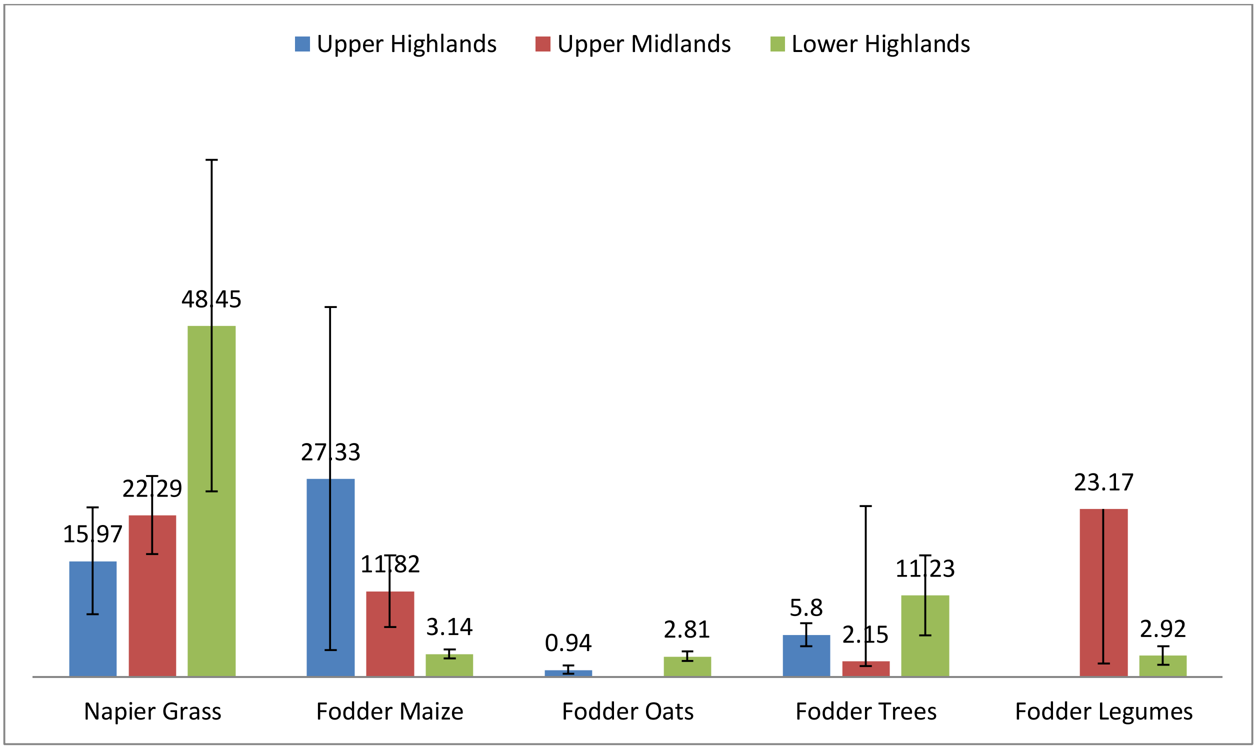

Figure 3: Amount of fodder produced in tons per acre by AEZ and fodder type

On average the lower highlands had the shortest distance to market (table 6). Therefore this could be the reason which might be influencing high productivity due to easy access to inputs and market for the produce.

4.3. Variations in yield of the fodder across the AEZ

A one-way ANOVA test of the variability of yield across AEZ's suggested there was a significant difference (P=0.035) in yield of Napier grass across the three AEZ's. The post hoc analysis showed that there was a significant difference between the upper highlands and lower highlands (table 7); this suggests that Napier grows better in the lower highlands than in the upper highlands given the set of inputs. There was also a significant difference (P=0.019) in yield of fodder trees across the three AEZ's. The post hoc analysis showed that there was a significant difference between the lower highlands and upper midlands (table 7), this suggests that fodder trees grows better in the lower highlands than in the upper highlands given the set of inputs.

Table 7: ANOVA analysis of yield between LH, UM and UH for the adopted fodder

Source	F	Prob>F	Bonferroni
Napier Grass	3.58	0.035**	Upper highlands different from lower highlands (P=0.046)
Fodder Maize	0.64	0.053*	
Fodder Oats	2.80	0.123	
Fodder Trees	4.48	0.019**	lower highlands different from Upper midlands (P=0.016)
Fodder Legumes	0.06	0.810	

**, and * indicates significance at 5% and 10%, respectively

The results from the one-way ANOVA test of the variability of productivity across AEZ's for fodder maize and fodder legumes (table 7) suggested that there was no significant difference in yield of the two across the three AEZ's. This suggests that the costs of production of maize and fodder legumes in the three AEZ's are the same. There is no significant difference in yield when growing them in the three AEZ's.

4.4. Gross Margins and Cost Estimates of the Selected Technologies

The costs of feed technologies being promoted for dairy cattle feeding among smallholder farmers in the three agro ecological zones in Kenyan highlands were estimated using equation 1, 2 and 3. Overall labor contributed more to the variable cost followed by fertilizer and fungicides (table 8 & appendix 3). These results agree with Guthiga *el al.* (2007) who found that hired labour and fertilizer costs were significant in influencing profits in small holder farms in Kenya. Amaza *el al.*, (2006) also found similar results in his research on identification of factors that influence technical efficiency of food crop production in Nigeria. The gross margins for Napier were high in the Lower highlands due to the high yield attained as discussed earlier. This may be attributed to favorable climate. The upper midlands were having losses in Napier production. The lower highlands had losses in fodder maize and this is attributed to inefficiency in allocating resources especially labor. The rest of the fodder had profits with fodder trees recording very high profits in the Upper highlands and fodder legumes in the upper midlands. This may be due to high yield produced in the respective regions with favorable climate. As shown on table 8 and appendix 3, the cost of planting material, fungicides and pesticides is very minimal in all agro ecological zones. Generally most farmers do not use pesticides and fungicides.

Table 8: Average Estimated Costs of Production (Averages per AEZ) in USD/ acre/year

Upper Highlands Returns	**Napier Grass**	**Fodder Maize**	**Fodder Oats**	**Fodder Trees**	**Fodder Legumes**
Yield per acre per year (tons)	16.0	27.3	0.9	5.8	0.0
Price per ton (USD)	15.0	42.2	361	342.5	324
Gross output (USD)	240	1153	339	1987	0
Variable costs/acre					
Planting materials	30.2	16.8	57.7	63.5	0.0
Fertilizer/manure	224.7	58.2	138.4	217.2	0.0
Pesticides, herbicides, fungicides	3.2	6.6	4.4	2.0	0.0
Labour	216.2	148.1	115.5	311.6	0.0
Other cost	0.0	0.0	0.0	0.0	0.2
Total Cost	**474.3**	**229.6**	**316.0**	**594.2**	**0.2**
Gross Margin	**-235**	**924**	**23**	**1392**	**0**

Note: Exchange rate: 1 US dollar = 83 shillings (approximately) during study period (CBK, 2012).

4.5. Variations in total variable cost of the fodder across the AEZ

A one-way ANOVA test of the variability of total variables costs across AEZ's suggested there was a significant difference (P=0.006) in variable costs of Fodder trees across the three AEZ's. The post hoc analysis showed that there was a significant difference between the lower highlands and upper midlands (table 9), this suggests that it's cheaper to grow fodder trees in the lower highlands than in the upper midlands given the set of inputs. There was also a significant difference in variable costs of Napier grass and fodder oats at 10% significance level. The rest of the fodder was not showing any significant differences. This suggests that the costs of production of maize, oats and fodder legumes in the three AEZ's are the same given the set of inputs.

Table 9: ANOVA analysis of cost between LH, UM and UH for the adopted fodder

Source	F	Prob>F	Bonferroni
Napier Grass	3.00	0.058*	
Fodder Maize	0.17	0.84	
Fodder Oats	4.39	0.056*	
Fodder Trees	4.48	0.006**	Lower highlands different from Upper midlands (P=0.004).
Fodder Legumes	0.01	0.927	

**, and * indicates significance at 5% and 10%, respectively

4.6. Cost/benefit of each promoted feed technology

A one-way ANOVA test of the variability of profitability across AEZ's suggested there was a significant difference (P=0.09) in profits of Napier grass across the three AEZ's. The post hoc analysis showed that there was a significant difference between the upper highlands and lower highlands (table 11), this suggests that it is more profitable to grow Napier in the lower highlands as opposed to the upper highlands given the set of inputs.

Table 10: AEZ Mean and Standard Errors (USD per acre/year)

	Average and Standard Error of Profit		
Source	**Upper Highlands**	**Upper midlands**	**Lower highlands**
Napier Grass	-360.86 (176.85)	13 (76.05)	16 (73.08)
Fodder Maize	923.79 (981.77)	-47.40 (69.59)	-109.09 (30.37)
Fodder Oats	199.91 (182.69)	0*	913.33 (259.92)
Fodder Trees	1064.29 (437.79)	458.75 (196.36)	750.19 (302.35)
Fodder Legumes	0*	-14.83 (249.00)	154.67 (203.93)

**fodders were not existent in the AEZ*

Table 11: ANOVA analysis of Profit between LH, UM and UH for the adopted fodder

Source	F	Prob>F	Bonferroni
Napier Grass	2.85	0.0856*	Upper highlands different from lower highlands (P=0.10)
Fodder Maize	3.11	0.1182	
Fodder Oats	0.01	0.9326	
Fodder Trees	3.11	0.1182	
Fodder Legumes	3.11	0.3266	

**, and * indicates significance at 5% and 10%, respectively

The results from the one-way ANOVA test of the variability of profitability across AEZ's for fodder maize (table 11) suggested that there was no significant difference in profits of fodder Maize across the three AEZ's (P= 0.1182). There is no significant difference in profits when growing fodder in the three AEZ's.

The oats were not grown as fodder in the upper midlands and the ANOVA results revealed that there was no significant difference (P=0.9326) in growing fodder oats in the upper highlands and lower midlands (table 11).

The results from the one-way ANOVA test of the variability of profitability across AEZ's for fodder tress (table 11) suggested that there was no significant difference in profits of fodder trees across the three AEZ's (P= 0.1182).

Finally the fodder legumes were not present in the upper midlands. The results from the one-way ANOVA test of the variability of profitability across upper highlands and lower highlands agro ecological zones for fodder legumes (table 11) suggested that there was no significant difference (P=0.3266) in profits of fodder legumes across the three AEZ's.

4.7. Socio-economic determinant of Profitability and Inefficiency of the adopted feed

4.7.1. Factors Explaining Efficiency

The stochastic profit frontier model results of the determinants of profitability and inefficiency when all the dairy farms are pooled together are shown in Table 12. During computation of profit, a few observations were dropped from the analysis either due to problems of missing values in the computation of profitability or of being outliers. Sigma squared (CI 1.52-5.57) and Gamma (CI 2.03-4.12) was significant indicating that the variation in profitability across the farms was significant and that inefficiency was an important cause of reduced profitability respectively. This is similar to results by Hyuha *et al.*, (2007), who found that farmers in eastern and northern Uganda do not operate on the profit frontier and it was caused by inefficiency due to low levels of education and limited access to extension services.

Table 12: Determinant of Profitability and Inefficiency

Determinants of Profitability		**Coefficient**	**Std-error**	**P>|z|**
Linear terms	Constant	-58.85	16.57	0.000***
Resources	Log cost of Labour/acre (Inlab)	46.69	12.33	0.000***
	Log other costs/acre (In Other)	9.18	3.75	0.015**
	Log Land under fodder cost/acre (In Land)	26.77	5.23	0.000
Square terms				
	Log Other costs/acre^2	-9.04	2.42	0.000***
	Log labor cost/acre^2	-1.31	0.35	0.000***
	Log land under fodder cost/acre^2	3.07	1.34	0.022**
Cross terms	In Labor # log InLand			0.000
		-8.13	1.61	
	In fodderland #In other costs	0.30	0.76	0.697
	In other inputs # In labor	12.41	1.30	0.064*

Determinants of Inefficiency				
Social economic Factors	Gender of Farmer (0=Male, 1=otherwise)	-2.58	o.77	0.001***
	Years of experience in Fodder production	0.096	0.035	0.006**
	Other Occupation of Farmer	1.799	0.659	0.006**
	Size of farm in acres	-0.47	0.13	0.000***
	Scale of Farming (Small, Large)	2.098	0.76	0.006**
	AEZ			
	Upper Midlands	4.60	1.35	0.001 ***
	Lower Highlands	6.572	1.796	0.000 ***
	Sigma-squared	-1.45***	1.03	
	Gamma	-0.264	0.53	

***, **, and * indicates significance at 1%, 5% and 10%, respectively

Number of iterations = 10

Log likelihood function = -14.57

Mean efficiency =34%

Min efficiency= 0.99

Max efficiency = 82%

Variance= 9.53e-o6

The factors determinant of profitability showed that labor (P=0.000) related positively to feed cost which shows that Labour is an important factor in feed production. These results are consistent with the prior expectations. Similar results were obtained by Rahman (2003) who found that labor had a share of 44% towards contributing to the variable inputs towards modern rice production. Similar findings are reported by Guthiga et al. (2007); Amaza et al. (2006) and Abdulai and Huffman (2000). Other input costs and land under fodder were significant at 5% and 1% respectively and they also related positively to feed cost. This means that they are also important factors in feed production (Table 12)

Table 12 shows the factors accounting for inefficiency in fodder production. Our prior results expected were that other occupation of HH and AEZ would have negative effect on efficiency. While experience and scale of farming would have positive effects and finally gender and land size would have both positive and negative effects on efficiency. The actual findings show that the coefficients of the factors hypothesized are significantly different from zero with consistent expected signs for other occupation, scale of farming, experience, gender and AEZ. Among the hypothesized socio economic factors that explain efficiency, Gender and Land size were found to be negative in influencing efficiency. All variables considered to affect inefficiency were significant (Table 12). Gender of a farmer had an effect on efficiency of feed production. Size of farm in acres was found to highly influence inefficiency positively (P=0.000). This meant that farmers with large land sizes were more inefficient as compared to those with smaller land. Farmers with small land sized had to use their scarce resources better than those with large land sizes. Scale of farming together with occupation of farmer also influenced inefficiency, significant at 1%confidence level. The years in farming experience was significant at 99% confidence level. This is in line with previous studies and prior expectations. This means that farmers who have been involved in fodder production for a long time were likely to be more efficient than late entrants in farming fodder to efficiently use inputs. Similar results supported by work done on technical profit efficiency in Nigeria, Pakistan and Bangladesh (Oladeedo and Oluwaranti, 2012; Ali and Flinn, 1989 and Rahman, 2003).

4.7.2. Profit Efficiency

The results on efficiency are tabulated on Table 13. On average, the overall profit efficiency score was low (34%). This means that on average Kenyan farms producing dairy cattle feed could increase their profits by 66% by improving their technical and allocative efficiency. The farms in the upper midlands were more efficient (37%) compared to the rest (table 13). These results show a wide variation in profit efficiency across all AEZ's especially the lower highlands (range 0.9% to 82%) and overall which is similar to past research. Ali and Flinn (1989) reported mean profit efficiency of 0.69 (range 13% to 95%) for basmati rice producers of Pakistan Punjab. These findings imply that farmers in the Kenya highlands can greatly increase their profits if they improve their technical and allocative efficiency in dairy feed production. The upper midlands and lower highlands had the most farmers operating at half the efficiency rate (40%). Few farmers in the upper midlands were operating at the half efficiency level (29%). Overall, 40% of the sampled farmers operated at half the optimal production efficiency levels.

Table 13: Profit Efficiency

AEZ	Average Profit Efficiency	Min	Max	Median	Standard Deviation
Upper Highlands	32%	7%	68%	29%	0.26
Upper Midlands	37%	2%	75%	40%	0.22
Lower Highlands	33%	0.9%	82%	39%	0.21
Overall	34%	0.99%	82%	40%	0.22

CHAPTER FIVE

5.0. CONCLUSIONS AND RECCOMENDATIONS

This study set out to estimate differences in yield, cost and technical efficiency in dairy fodder production in the Kenyan highlands. The main objective was to enhance adoption of fodder through knowledge generation on costs and benefits of fodder in the selected AEZ's of the Kenyan highlands. ANOVA was used to determine zones that are significant different from the rest and stochastic profit frontier method were used to generate technical efficiency using translog, as the functional form.

The above-mentioned analysis of production function indicates that labor is the most important input affecting dairy cattle fodder production in the study area. The Anova results show that Napier grass has comparative advantage in the lower highlands. These results indicate the possibility of diverting part of capital from significant inputs to labor and fertilizer. This can be supported by the highest share of the total cost accounts for labor, followed by cost of fertilizer in all scale of farming. Based on the findings, the following general conclusions are drawn:

I. Farmers in the lower highlands were producing more Napier grass due to favorable climate and also had significant profits compared to those in the upper highlands. It's therefore advisable for farmers in the lower highlands to adopt Napier production. Therefore, farmers in the upper highlands should improve on their methods of production or consider outsourcing the Napier grass from other regions.

II. The results also show that there was a significant difference (P=0.019) in fodder tree production between the lower highlands and upper highlands. Therefore, farmers in the lower highlands have favorable climatic conditions for growth of fodder frees compared to those in upper highlands. The rest of the feeds showed similar advantages meaning regardless of which AEZ one is situated in, the yield would be similar. Its advisable for farmers in the lower highlands to take advantage of the benefits and adopt fodder trees.

III. The costs of fodder trees across the three AEZ's were significantly different. Therefore, farmers in the lower highlands are better off in terms of input costs compared to the upper midlands. Further research needs to be carried to find out what exactly inflates cost of inputs in the upper midlands.

IV. Only Napier grass was profitable to grow in the lower high lands due to low costs of production and yield. Therefore adoption of Napier is inevitable in the lower highlands. The rest of the fodder crops under study showed no significant differences in profits.

V. In order to increase profits, there is need to reduce on labor cost. Increased labor efficiencies should be sought through use of improved mechanization or batch planting in order to reduce costs and increase profits.

VI. Gender influenced efficiency; both male and female should therefore be encouraged to venture in fodder production. The farms that had large land sizes turned to be less efficient as compared to the smaller farms. This could be due to farmers focusing on other farming enterprises and lack of labor or mechanisation. Therefore it is important for large farms to consider focusing on improving their balance sheets on feed production.

VII. More experienced farmers were more efficient than those who were new in the enterprise. It would be important for the extension departments in the area to intensify their work to increase knowledge on fodder production.

VIII. Interventions to improve the productivity and efficiency of feed production would increase profitability and in the long run milk production in the given areas. The proportion of land under fodder in all AEZ's is small (9%) hence the need to intensify land use through increase in use of improved seed, intercropping, fertilizer use and conservation tillage to maximize production.

IX. To tackle the problem of inefficiency, a holistic approach to develop a feed production plan for farmers is required in attempts to improve efficiency and profitability. Therefore, profitability and efficiency can be increased by also factoring in the socio economic factors that contribute to inefficiency when planning for feed production. The feeding policies targeting smallholder dairy farmers should incorporate the farmer's social and economic factors as well.

X. This study has shown that profit inefficiencies can be observed across farms at all levels of production. Therefore to increase efficiency, farmers should visit their local extension agents to help them compute their break-even costs of production based on prevailing input costs. Once calculated, policy makers and planners who make decisions related to design of appropriate policies and investment to support smallholder dairy development can use these result estimates. In addition, alternative labor saving technologies can be used to reduce the cost of labor such as drought power and mechanisation because it is the main factor that reduces profitability.

XI. Improving the extension ratio and increasing the number of model farmers in the area could increase transfer of technology and innovations hence improve efficiency. Therefore farmers should be encouraged to participate more in farmer groups to improve their technical know-how in farming. Finally through better price and increased efficiency, farmers will be able to increase their feed production and profitability.

XII. Finally farmers in areas that don't have benefits in growing the promoted fodder should capitalize on the benefits in order to increase availability and accessibility of the crop to other farmers. In these regard dairy cooperative being established and operating should participate in these inputs supply for their members and non-members dairy farmers so that they can harness their advantage. This will result in reduced cost of feed that could be easily accessible and timely available in all areas. Moreover, dairy farmer in disadvantaged areas should be encouraged to establish linkage with their neighbors who have advantage in growing the crops in the question.

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APPENDICES

Appendix 1: Productivity of Selected Fodder

Fodder Name	Residue yield (kg DM/ha)	Residue ME (MJ /kg DM)	ME Yield (MJ/ha)	Residue CP (g/kg DM)	CP Yield (kg/ha)
Cut Grass	2250	8.16	18360	100	225
Desmodium	10280	9.85	101258	108	1110
Dolichos Lab lab	9711	6.8	66034.8	254	2467
Finger Millet straw	3000	5.7	17100	96	288
Grass Hay	3000	7.57	22710	43	129
Groundnuts (haulms)	2500	7.2	18000	125	313
Kale (rejects)	6900	11	75900	150	1035
Legume Hay	3500	5.7	19950	290	1015
Leucaena	13250	6.5	86125	261	3461
Lucerne	12000	7.2	86400	180	2160
Maize grain	5625	13.5	75937.5	94	529
Maize Stover Dry	3000	3.7	11100	92	275
Maize Stover Green	3500	9.2	32200	77	270
Napier grass	26,000	9.12	237120	70	1820
Natural Pasture	4100	8.2	33620	66	271
Oats	6700	6.7	44890	34	228
Planted pasture	8000	9	72000	65	520
Sesbania	10000	7.74	77400	282	2820
Sorghum stover	4016	6.28	25220.48	475	1908
Sorghum straws	4016	7.8	31324.8	42	169
Soya beans (meal)	2784	9.2	25612.8	174	484
Soya beans (meal)	2100	12.3	25830	130	273
Soya beans (straw)	3800	5.9	22420	60	228
Sugarcane (tops)	2562	8.37	21443.94	590	1512
Sunflower (seed cake)	1080	15	16200	100	108
Sweet potatoes (vines)	2470	8.87	21908.9	185	457
Unimproved pasture grass	4100	1.7	6970	120	492
Vetch	4633	8.6	39843.8	178	825
Weeds	2700	8.16	22032	100	270
Wheat (straw)	9000	8.2	73800	98	882

Source (EADD, 2010)

Appendix 2: Nutritive value of Adopted fodder in Kenya

Feed	Type of forage	Dry Matter (%)	Moisture content (%)	Estimated Protein (%)	Energy MJ of ME/kg
Coach grass	Grass	30.20	69.80	8.80	8.20
Cut grass	Grass	28.00	72.00	10.00	8.16
Kikuyu grass	Grass	20.00	80.00	12.00	9.50
Napier grass (>6 ft)	Grass	24.00	76.00	5.00	8.79
Napier grass (1 ft)	Grass	12.10	87.90	9.20	9.12
Napier grass (2 ft)	Grass	12.60	87.40	7.40	9.00
Napier grass (3 ft)	Grass	13.40	86.60	7.00	9.00
Napier grass (4 ft)	Grass	14.40	85.60	6.50	9.00
Napier grass (5 ft)	Grass	15.50	84.50	6.20	8.95
Napier grass (6 ft)	Grass	18.70	81.30	6.00	8.95
Napier grass Average size	Grass	15.81			
Rhodes grass	Grass	90.00	10.00	6.30	8.20
Star grass	Grass	30.00	70.00	11.00	8.16
Columbus/Sudan silage	Silage	45.00	55.00	10.80	4.77
Maize silage	Silage	32.00	68.00	8.00	10.50
Napier silage	Silage	28.00	72.00	7.50	9.00
Calliandra leaves	Tree fodder	25.00	75.00	26.30	9.00
Leucaena leaves	Tree fodder	28.00	72.00	23.00	8.40
Sesbania leaves	Tree fodder	28.00	72.00	28.20	7.74
Kales	Vegetable	20.00	80.00	12.00	9.25
Vegetables	Vegetable	11.00	89.00	33.00	12.50

Source (EADD, 2010)

Appendix 3: Questionnaire

QUESTIONNAIRE IDENTIFICATION

COUNTRY: [KENYA]

HUB [_____________________________] (NAME)

QUESTIONNAIRE ID : [ ]

(i) TYPE OF FODDER/FORAGE GROWN ON THE FARM [____] CODE

Fodder/forage type		
1=Napier grass	4=Calliandra	7= Lablab
2=Fodder maize	5=Sesbania	8=Desmodium
3= Fodder Oat	6= Lucerne	9=Mucuna

(ii) FODDER/FORAGE GROWN AT:

[ ] Small scale

[ ] Medium scale

(*Refer to protocol for scale threshold and tick one applicable*)

(iii) ***Specify land unit to be used in answering questions on land size [ ]***

(Code): 1=Acres, 2=Hectares, 3=other (specify) **_______________**

(iv) ***All costs and revenues should be in local currency***

Enumerator's name: ______________________________ Enumerator code_____________

Date of interview (dd/mm /yy) /___/___/2012

Owner's/Household head Name________________________________ [full name)

Respondent's name: ____ [full name)

(Try to interview the person in charge of the activity)

Telephone number (Household head or respondent): __________________________

Respondent's position in the household [_____] (code)

Position code				
1=Head	2=Spouse	3=Child	4= Hired labor	5= Other (specify)__________

Sex of the respondent [ ] male [ ] female (tick)

Age of the respondent [ ] years

GPS COORDINATES: X ___________________________ (0.)

Y ___________________________ (36.)

A HOUSEHOLD CHARACTERISTICS

A1.0 Provide the following details about the household head

1.1 Sex (code): 1 = Male, 2 = Female [______] code

1.2 Age [______] (years)

1.3 Main occupation [______] (code)

Occupation Codes	
0=None	4=Retired
1=Farmer/livestock keeper	5= Civil servant
2=Employee in private enterprise	6= Other (specify)_______
3=Businessperson/own business	

1.4 Years in fodder farming [______] **(years)**

Move 1.1-1.4 immediately after household name

A2.0. Do you keep cattle? [__] 0=No, [__] 1=Yes

2.1 Indicate the heads and breed of cattle kept on the farm

Animal type (codes)	**Breed** (codes)	**Number kept on the farm**

99 to go to A3.0		

ANIMAL TYPES	BREEDS		
1 =Heifers (>1 year)	**1** Friesian (pure)	**7** = Guernsey (pure)	**13**=Nganda
2 =Cows (calved at least once)	**2** = Friesian (cross)	**8** = Guernsey (cross)	**14**=Nsoga
3= Bulls (> 1year)	**3** =Ayrshire (pure)	**9** = Sahiwal	**15**=Other (specify)_____
4= Castrated males (>1year)	**4** =Ayrshire (cross)	**10** = Boran	
5= Male calf (<1 year)	**5** = Jersey (pure)	**11**= Local Zebu	
6=Female calf (<1 year)	**6** = Jersey (cross)	**12**=Ankole	

A3.0 Provide details about land holding and allocation to fodder type specified on bullet (i)

(0 if no rent- in/out land and price)

Land holding and allocation to the fodder	
3.1 What is your total land size (include rented)?	[______]
3.2 How much of this land have you rented?	[______]
3.3 How much rent do you pay per year?	[______] (Local currency)
3.4 How much land does this fodder type occupy?	[______]
3.5 Do you have some of this fodder on the rented land? [__] 0=No, [__] 1=Yes	[______]

3.6 If yes to 3.**5**, how much of the rented land is occupied by fodder?	[______]
3.7 Did the rent-in land have this fodder type already established at the time of renting? **Code:** 0=No, 1=Yes. If yes, what proportion of this land was already under this fodder type?	[______] [______]%
3.8 What is the maturity period of the fodder stand/ forage?	[______] months
3.9 What is the productive period of the fodder/forage?	[______] months

A 4.0 All data collected below relates to a specific plot under the fodder. Make sure that all costs and revenues relate to this particular plot. Refer to 3.4

B. PLANTING MATERIAL AND NURSERY ESTABLISHMENT

B1.0 Main source and cost of planting material for fodder

1.1 Source of planting material	**Tick main source**	**Total cost**
1=Purchased seeds/seedlings/cuttings/splits	[ ]	[ ]
2=From own nursery/seedlings	[ ]	***If own nursery/seedlings go to B 2.0***
3=Own cuttings/Splits	[ ]	[ ]
4=Other (specify)_____________	[ ]	[ ]

99 to go to Section B2.0

If planting material is sourced from sources other than 2 skip to section C

B2.0 Provide details on nursery establishment (Applicable to fodder shrubs)

2.1 Did you establish a nursery for this type of fodder? [__] 0=No, [__] 1=Yes

	Total cost (Local currency)
2.2 When was the nursery established? [ ] year	
2.3 Total labor cost for the preparation of nursery bed	[ ]
2.4 Total labor cost for sowing seeds in the nursery bed	[ ]
2.5 Other costs incurred in the establishment of nursery:	[ ]
2.5.1 Water	[ ]
2.5.2 Pesticides/herbicides/fungicides	[ ]
2.5.3 Other (specify)____ 99 if no other cost ï skip ot 2.6	[ ]
2.5.4 Other (specify)__ 99 if no other cost ï skip ot 2.6	[ ]
2.5.5 Other (specify)_ 99 if no other cost ï skip ot 2.6_	[ ]
2.6 How long does the nursery take to mature? Unit code: [ ] No. of units [ ] (**Code:**1=week, 2=month 3=Other (Specify______)	
2.7 Were all the seedlings utilized in fodder establishment? [__] 0=No, [__] 1=Yes	
2.8 If NO, how were the remaining seedlings utilized? **[ ]** **(Code:**1=Sold 2= Given out, 3=Other (specify)_____	
2.9 If sold, how much was total revenue generated?	[ ]
2.10 If given out, what is the value of seedling given away?	[ ]

C PLANTING

C1.0 Land preparation (0 if no costs incurred)	Unit code	No. of Units	Unit cost	Total cost Local currency
1.1 Did you till the plot under fodder in preparation of fodder establishment? [___] 0=NO [___] 1=YES; if NO skip to C2.0				
1.2 If yes, how much did it cost to till the plot under fodder? **Unit code: 1= man-day, 2=tractor, 3=oxen plough**	[ ]	[ ]	[ ]	[ ]
C2.0 Establishing forage/fodder field				
2.1 When the fodder established? [ ] year				
2.2 Cost of labor used in transferring and planting the seedlings in the field? **Unit code: 1=man-day**	[ ]	[ ]	[ ]	[ ]
2.3 Cost of fertilizer used in planting? Unit code: 1=kg	[ ]	[ ]	[ ]	[ ]
2.4 Cost of manure used in planting?				
2.5 Do you top dress fodder? [___] 0=NO [___] 1=YES If NO, skip to C3.1 2.5.1 If yes, how many times did you top dress the fodder in the last one year? [___]				
2.6 Cost of fertilizer used to top dress in the last one year? **Unit code: 1=kg, 2=Litres**	[ ]	[ ]	[ ]	[ ]
2.7 Cost of manure used to top dress in the last one year? **Unit Code; 1= Kgs, 2=Donkey cart, 3=Standard sack (90kg), 4= wheelbarrow, 5=other**	[ ]			

(specify)______________				
C3.0 Weeding, pest and disease control				
3.1 Do you use chemicals to control weeds, pests and diseases on plot under fodder?[___] 0=NO [___] 1=YES If NO, skip to 3.4				
3.2 If yes to 3.1 indicate (for the last one year) the cost of: 3.2.1 Herbicides 3.2.2 Pesticides 3.2.3 Fungicides *(where applicable)* **Unit code: 1=Liters**	[ ] [ ] [ ]	[ ] [ ] [ ]	[ ] [ ] [ ]	[ ] [ ] [ ]
3.3 How many times did you weed the plot under fodder in last one year? (probe by season) [ ] 0 if NO weeding is done, skip to 3.5 3.3.1 How much did labor cost in weeding the plot under fodder **(at each weeding)? Unit code: 1=man-day**	[ ]	[ ]	[ ]	[ ]
3.4 How many times did you control pest on the plot under pasture in last one year? [ ] 0 if NO pest control is done, skip to 3.5 3.4.1 Cost of labor in controlling pest in the plot under fodder in last one year? **Unit code: 1=man-day**	[ ]	[ ]	[ ]	[ ]
3.5 How many times did you control disease(s) on the plot under pasture in last one year? [ ] 0 if NO disease control is done, skip to D 3.5.1 Cost of labor in controlling disease(s) in the plot under fodder in last one year? **Unit code: 1=man-**				

day	[ ]	[ ]	[ ]	[ ]

D HARVESTING AND TRANSPORTATION

D1.0 Indicate the months of harvest, quantities harvested from the plot of fodder and cost of labor in one year.

Month	**Season (Code: 1=Wet 2=Dry)**	**Quantity**		**Total labor cost (Local currency)**			**Unit Code**
		Unit code	**No. of units**	**Harvesting**	**Transport from field to storage**	**Processing (e.g chopping, drying, wilting)**	1= Kgs
Jan	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	2 = Standard sack (90kg)
Feb	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	3= Tonnes
March	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	4 =Acres
Apr	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	5=Other (specify)
May	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	
Jun	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	
Jul	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	
Aug	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	
Sep	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	
Oct	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	
Nov	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	
Dec	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	

99 to end section ï go to section G

1.2 Do you conserve this type of fodder/forage? [___] 0=NO [___] 1=YES

(If Yes, please fill the conservation questionnaire)

E PROCESSING AND STORAGE

E1.0 Cost of storage (0 if cost not incurred)

Cost of storage of fodder	Fodder
1.1 Do you have a storage facility?	[___] 0=NO [___] 1=YES
1.2 If yes, when was it constructed?	[ ]year
1.2 What is the value of the storage facility? (***or how much would it cost to hire a storage facility***)	[ ] local currency
If can't estimate value of storage facility, 1.3 Tick materials used to construct storage shed: (0 where cost was not incurred) 1.4.1 Timber, (99 if materials not used ï skip to 1.5) 1.4.2 Iron sheet 1.4.3 Thatch 1.4.4 Polythene bags 1.4.5 Other (specify) 1.5 Area under shed (sq. meters)	[ ] [ ] [ ] [ ] [ ] [ ]
1.6 What is the approximate annual cost of repair/maintenance for the storage facility	[ ] local currency

F. REVENUE

F1.0 Provide details on revenue generated and/or lost from fodder given out, sold or spoilt in the last one year

	Unit code	***No. of units***	***Total value***
1.1 Have you sold some of the fodder harvested in the last one year? [___] 0=NO [___] 1=YES 1.2 If yes to 1.1, how much was sold and at what value?	[ ]	[ ]	[ ]
1.3 Have you given some of the fodder harvested in the last one year? [___] 0=NO [___] 1=YES 1.4 If yes to 1.3, how much was given out and what was the total value?	[ ]	[ ]	[ ]
1.5 Have you lost any of the harvested fodder through			

spoilage in the last year? [___] 0=NO [___] 1=YES 1.6 If yes to 1.5, how much was lost through spoilage and what was the total value?	[ ]	[ ]	[ ]

Unit Code	
1= Kgs	4 =Acres
2 =Standard sack (90kg)	5=Other (specify)
3= Tonnes	

G. EQUIPMENT

G1.0 Cost of equipment (Provide price and year of purchase where applicable)

Equipment used in forage/fodder production	Do you own? 0=No, 1=Yes	No. owned	Price at purchase/unit (Local currency)	Total cost (Local currency)	Year of purchase	Percentage utilization in fodder production
1.1 Tractor	[ ]	[ ]	[ ]			[ ]
1.2 Fork jembe	[ ]	[ ]	[ ]			[ ]
1.3 Hoe	[ ]	[ ]	[ ]			[ ]
1.4 Bush knife	[ ]	[ ]	[ ]			[ ]
1.5 Spray pump	[ ]	[ ]	[ ]			[ ]
1.6 Wheel barrow	[ ]	[ ]	[ ]			[ ]
1.7 Scotch/donkey cart	[ ]	[ ]	[ ]			[ ]
1.8 Pick-up	[ ]	[ ]	[ ]			[ ]
1.9 Canter	[ ]	[ ]	[ ]			[ ]
1.10 Storage	[ ]	[ ]	[ ]			[ ]

materials (e.g gunny bags)						
1.11 Other (specify)____________	[ ]	[ ]	[ ]		[ ]	[ ]
1.12 Other (specify)____________	[ ]	[ ]	[ ]		[ ]	[ ]

99 to end section

Appendix 4: Average Estimated Costs of Production in USD/acre/year

Upper Midlands Returns	Napier Grass	Fodder Maize	Fodder Oats	Fodder Trees	Fodder Legumes
Yield per acre per year (tons)	22.3	11.8	0.0	2.15	23.2
Price per ton (USD)	15.0	42.2	361	342.5	324
Gross output (USD)	335	498	0	736	7507
Variable costs/acre					
Planting materials	21.6	13.6	0.0	53.7	55.4
Fertilizer/manure	71.4	44.8	0.0	36.4	28.2
Pesticides, herbicides, fungicides	0.0	2.9	0.0	0.4	18.2
Labour	207.3	165.0	0.0	145.4	208.6
Other cost	0.0	0.0	0.0	0.0	0.0
Total Cost	**300.3**	**226.2**	**0.0**	**235.9**	**310.4**
Gross Margin	**34**	**272**	**0**	**500**	**7197**

Lower Highlands Returns	Napier Grass	Fodder Maize	Fodder Oats	Fodder Trees	Fodder Legumes
Yield per acre per year (tons)	48.5	3.1	2.8	11.2	2.9
Price per ton (USD)	15.0	42.2	361	342.5	324
Gross output (USD)	727	133	1014	3846	946
Variable costs/acre					
Planting materials	28.6	17.8	31.5	393.8	161.0
Fertilizer/manure	85.6	70.4	36.0	61.0	37.1
Pesticides, herbicides, fungicides	1.4	0.0	0.0	1.2	0.0
Labour	227.9	161.0	137.6	140.9	181.4
Other cost	0.0	0.0	0.0	0.0	0.0
Total Cost	**343.6**	**249.2**	**205.0**	**596.8**	**379.4**
Gross Margin	**383**	**-117**	**809**	**3249**	**567**

Note: Exchange rate: 1 US dollar = 83 shillings (approximately) during study period (CBK, 2012).

Appendix 5: Small-scale and large-scale land sizes for the various technologies.

Country	**Kenya**	
Production System	Small-scale acreage	Medium-scale acreage
Napier grass	<=2	>2
Rhodes grass	<=10	>10
Natural pasture	<=10	>10
Lucerne/desmodium	<=2	>2
Lablab/mucuna	<=2	>2
Fodder shrubs	<=2	>2
Maize stovers	<=5	>5
Wheat	<=10	>10
oat straws	<=10	>10