SOCIO-ECONOMIC ANALYSIS OF FODDER LEGUMES: THE CASE OF CALLIANDRA AND DESMODIUM IN SMALLHOLDER DAIRY FARMS OF EMBU DISTRICT, KENYA

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A Thesis submitted to the Graduate School in partial fulfilment for the requirements of the award of a Master of Science Degree in Agricultural Economics of Egerton University

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DECLARATION

I hereby declare that this is my original work and has not been presented in this, or any other University for the award of a degree.

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RECOMMENDATION BY SUPERVISORS

We declare that this work has been done with our approval as University supervisors.

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LIST OF ACRONYMS

CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro International de Mejoramiento de Maiz Y Trigo (International Maize & Wheat improvement centre)
CP	Crude protein
DM	Dry Matter
GDP	Gross Domestic Product
Ha	Hectare
ICRAF	International Centre for Research in Agro forestry
ILRI	International Livestock Research Institute
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute
Ksh	Kenya Shillings
LP	Linear Programming
LU	Livestock Unit
MD	Man Days
NAFRP	National Agro forestry Research Project
NGOs	Non-Governmental Organizations
SPSS	Statistical Package for Social Sciences
US$	United States Dollar

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DEDICATION

In memory of my parents Joseph and Correty Kipkoech who inspired me to pursue this course

ABSTRACT

The central highland of Kenya is characterized by small land holdings, and as the size of land holdings continue to decline due to subdivisions, most livestock feeds will have to come from cropped land. World Agroforestry Centre together with partner institutions have introduced fodder legumes (calliandra and desmodium) with the aim of alleviating feed shortage. The purpose of this study was to examine the economic benefits of the fodder legumes when they were used as supplements for increasing milk production under different access to markets, cattle management levels and by gender in Embu district, Kenya. Current uses of the fodder legumes and farmer innovations based on farmers' experience with the technology were also assessed. Data was collected using a questionnaire that was administered to 60 randomly selected farmers who have adopted fodder legumes in Embu District. Factors affecting farmer innovation were analysed using the logit model. Partial budgets were used to analyse data to determine the net benefits when fodder legumes were used as supplements under different scenarios. Descriptive statistics were also used.

The study showed that economic benefits of using calliandra as a supplement were higher ($p>0.05$) in female managed farms and under high cattle management levels. For desmodium, higher ($p>0.05$) net benefits were realised in those farms managed by male farmers and medium cattle management level. Generally, calliandra farmers get higher ($p<0.05$) net benefits compared to desmodium farmers. Other benefits derived from fodder legumes were provision of fuel wood, fertility improvement, and improvement in animal health, which were mentioned by 50%, 48% and 38% of calliandra farmers respectively. Similarly 33% and 38% of desmodium farmers, mentioned fertility improvement and erosion control respectively. Weed suppression was cited by 17% of desmodium farmers. Farmers also modified the recommendations or did some experiments on their own, which included: drying calliandra and mixing with bran and using it as cattle or poultry feed, drying and mixing with indigenous fodder. Data from the farmer survey were analysed to assess the factors associated with farmer innovation. The results indicated education as the main socio economic factor that influenced ($p<0.05$) the decision to innovate in the case of calliandra. The study has helped identify farmer innovations and additional benefits of fodder legumes. These can be further explored to improve adoption of these legumes.

CHAPTER ONE

INTRODUCTION

1.1 Background

The livestock sub sector is important to the majority of Kenya's farmers who keep different types of animals such as cattle, sheep and goats. The sub-sector generates income for farmers through sale of animals and animal products. Livestock have been known to utilize by-products of cropping systems unwanted by human beings (e.g. crop residues), improve soil fertility through use of organic manure, even out utilization of family and hired labour through out the year and ensures more even distribution of income throughout the year. This is because livestock production may be planned to coincide with sales at any time of the year and hence reduce overall farm risk (Ndiritu, 1995; GoK, 1997).

Despite the role livestock play, lack of quality feeds especially during the dry season coupled with high cost of commercial concentrates is recognized as one of the key problems facing farmers throughout Sub Saharan Africa (SSA). Inadequate nutrition seriously impedes livestock production. This impediment causes low milk production (McIntire, 1992; Winrock International, 1992; Nyaata *et al.*, 2000).

Because commercial feedstuffs are expensive, livestock producers have regularly been forced to seek less costly alternatives. By-products from food and beverage processing like bran and oil meals represent such alternatives. Some of these have been used extensively as feeds and their use has resulted in more economical livestock production. But many other potentially valuable feed resources, which have substantial nutritive value and are available reasonably, have been under-utilised (National Research Council, 1983).

Agroforestry systems involving tree legumes appear to offer one means of addressing the problem of feed shortage/availability within the resource constraints and conditions that small scale dairy farmers operate e.g. ever increasing feed prices relative to milk prices (Nyaata *et al.*, 2000). Fodder legumes when fed to livestock as supplement to grasses and at times when fed alone can contribute favourably to animal performance (Mengich, 1994).

Also agroforestry reduces the risks farmers face from the input markets by providing home produced substitutes for purchased concentrates such as dairy meal (Franzel and Scherr, 2002). For example, in central Kenya farmers complain of unavailability of concentrates, difficulties in transportation because of poor road network and they are of

unreliable quality. With home produced *Calliandra calothyrsus* and *Desmodium intortum*, none of these problems arise. As compared to grasses, fodder from these legumes is rich in protein as the shrub leaves maintain their levels of protein even during dry season (Wambugu *et al.*, 2001; Murithi, 1998).

Calliandra calothyrsus (henceforth referred to as calliandra) can be used as a protein supplement, the basic diet normally being napier grass, crop residues or hay. Calliandra appears to be appropriate for small-scale dairy farmers, given their small land holdings, it can be planted along the contours, boundaries and around home compound hence take little land (Murithi, 1998). It can be grown in a wide range of climatic and soil conditions, from the sea level to the highlands, but performs best in coffee zones (Wambugu, 2002).

Farmers also value agroforestry practices involving fodder legumes for other reasons besides the products and services they provide. Other benefits of the legume in addition to being used as a fodder include: provision of firewood, bee forage and poles or stakes for supporting tomatoes and climbing beans. The legume also helps in improving fertility of the soil since it has root nodules that fix nitrogen from the air. Calliandra can also be used to stabilize soils and performs well in soil conservation (Wambugu, 2002). It can also be used as a boundary maker, a fence, and as an ornament. It also increases the butterfat content of milk, giving it a richer taste and creamier texture (Paterson *et al.*, 1998).

Whereas calliandra is integrated into different niches on smallholder farms *Desmodium intortum* is primarily grown as a companion crop to napier grass (*Pennisetum purpureum*) (Mwangi and Wambugu, 2002). *Desmodium intortum* (henceforth referred to as desmodium) is grown and harvested together with napier grass with the aim of improving the nitrogen supply to the cattle. Since the digestibility and the nitrogen content of napier grass declines rapidly as the grass matures, curtailing milk production, integration of desmodium into napier grass would result in higher dry matter and nitrogen content of the diet and thus alleviate the problem of protein deficiency (Mwangi, 2001). The yield of the mixture (napier grass + desmodium) is much higher than that of napier grass alone and apart from the improved supply of nitrogen, the higher DM would reduce the perpetual under feeding of dairy cows. The increase in DM yield and the higher nitrogen content of the diet would be expected to contribute towards alleviating protein deficiency and shortage of animal feeds on smallholder farms (Mwangi, 2001). The higher DM yield is therefore the additive effect of the legume

rather than its effect on grass performance. This would imply that the napier grass/legume mixture is possibly utilizing resources (soil, space etc) more efficiently, thus resulting in higher forage DM yield (Mwangi and Wambugu, 2002). Also, once desmodium is established, it suppresses weeds and the mixture does not require weeding saving the farmer substantial amounts of money.

Agricultural development demands continued innovation (Kibwana, 2000). Rhoades and Bebbington (1991) have stated that farmers, like researchers, are experimenters. Farmers, like most human beings, are curious and it is common for a farmer to set up an experiment just to test an idea that comes to mind. The nature of this farm-based spontaneous research has rarely been systematically studied. It is therefore, important that researchers and extensionists learn about such practices (innovations) in order to design better research programs and develop extension programs and popularise such practices among farmers under similar conditions (Abedin and Hague, 1991). Also, linking up farmer innovators from different areas who have been experimenting with similar ideas and types of technologies can be a source of inspiration to each other. This gives the farmers an opportunity to discuss the background of the local innovation and the benefits derived from them (Miiro *et al.*, 2001). The purpose of supporting farmer experimentation is to strengthen farmers' capacities to seek and try out new ideas so that they are better able to experiment and adjust to changing conditions (Reij and Waters-Bayer, 2001).

Though some work has been done to assess the benefits of fodder legumes like calliandra (Franzel *et al.*, 2002), much of the research has focussed on determining the net benefits realised by farmers without taking into account different settings (scenarios) in which farmers operate. This study in addition of determining the net benefits of calliandra, incorporated desmodium and the benefits were analysed under the following scenarios, gender, different cattle management levels and different markets accessibility. Farmer innovation, and current uses of fodder legumes and perception about their uses was also assessed.

1.2 Problem statement

Increasing cost of livestock feeds is viewed as a critical problem affecting the productivity of dairy cattle and the level of farm incomes of smallholder dairy farmers. Feed

costs account for an important proportion of variable costs in cattle production. Hence, technologies that would help reduce this cost should be adopted by farmers.

Adoption of agroforestry practices involving fodder legumes appear to be a promising option for increasing the income of the farmers by addressing the problem of shortage of feeds through provision of home produced supplements or substitutes. However, little information is available on economic benefits of fodder legumes under farmer- managed conditions. Hence, there is need to get information that can enable us to know the benefits of these alternative feed resources as this will enhance farmer adoption.

This study therefore focused on determining the net benefits of fodder legumes under different scenarios. In addition, farmer innovation and what farmers see as benefits of the practice will be assessed in order to provide feedback to researchers and extension agents for refining their extension messages.

1.3 Objectives

The general objective was to investigate the economic benefits of calliandra and desmodium among the smallholder dairy farmers.

Specific objectives were to:

1 Determine the net benefits of calliandra and desmodium when they are used as a supplement in milk production under different market accessibility, different cattle management levels and by gender.

2 Identify farmers' current uses of calliandra and desmodium and perceptions of their uses.

3 Identify farmers' innovations based on their experimentation with the technologies (calliandra and desmondium).

4 Assess the factors associated with farmer innovation.

1.4 Null hypotheses

The null hypotheses of the study were:

1 The net benefits of using fodder legumes (calliandra and desmodium) as supplement in milk production do not vary under different market accessibility, different cattle management levels and by gender.

2 The utilization of fodder legumes by farmers is similar.

3 There are no common innovations undertaken by farmers in the study area.

4 There is no relationship between farmer innovation and farm and household characteristics.

1.5 Justification of the study

Fodder legumes have a great potential for increasing the incomes of small- scale dairy farmers by addressing the problem of feed availability within the resource constraints and conditions under which these farmers operate. Given that the central highland of Kenya is characterized by small land holdings, which continue to decline due to subdivisions, most livestock feeds will have to come from cropped land. Farmers have adopted various agroforestry practices as means of addressing the problem of feed availability and hence alleviate the problem of poor animal nutrition. However there is limited information recorded on the benefits of legumes especially calliandra and desmodium among the smallholder dairy farms, specifically, the net benefits under different settings (scenarios) in which farmers operate. It is therefore necessary to assess the net benefits under different scenarios and what other benefits farmers derive from the legumes as demonstration of positive economic impact forms the basis for increased rationale for institutions to support extension for increased adoption. This study attempted to determine the net benefits realised by farmers under different access to markets, different cattle management levels and by gender

Also information on how farmers are using and modifying the practice (farmer innovation) and what benefits they obtain is important to researchers so that they can develop practices (extension programs) and popularise them among farmers under similar conditions. Like many agroforestry practices, fodder legumes spread slowly on their own. Therefore considerable effort in terms of training information and germplasm is needed. Information on farmer innovation can be disseminated through various methods for example farmer visits,

training and meetings. This helps in transferring knowledge of fodder legume technologies. Extension materials can also be developed to promote fodder legumes. Videos and simplified brochures for farmers can prove to be useful.

1.6 Scope and limitations

The study covered coffee/ tea/ dairy land use zone of Embu district. This is where on-farm trials and dissemination activities on fodder legumes (calliandra and desmodium) have been undertaken by farmers. The sample of farmers included those who have tested (adopted) fodder legumes; hence non-adopters were excluded from the study. Also it was not possible to interview many farmers with desmodium because of lack of comprehensive list of adopters and limited resources. Costs that varied due to introduction of technology (fodder legume) were taken into account and included in the budget in determining the net benefits of fodder legumes. This included the extra costs and benefits. Aspects of the operation (dairy) that remain constant were not examined.

The main assumption of the study was that farmers were concerned with costs and benefits of particular technologies i.e. they were concerned with either minimizing costs or maximizing net returns of one given enterprise.

1.7 Definition of terms

Adoption: A decision to make use of a new idea, practice or technology on a continued basis.

Agroforestry systems: Land use systems in which woody perennials (trees, shrubs, etc) are deliberately used on the same land management unit as agricultural crops, animals or both.

Crude Protein: Protein content estimated from total nitrogen content of the crop.

Farmer innovation/Farmer experimentation: Are incremental improvement in the farmers practices.

Fodder: Plant or plant parts eaten by browsing or grazing animals.

Fodder Tree: Fodder trees are those grown solely mainly or partly for the fodder they provide.

Logit model: A model that is based on cumulative logistic probability function.

Niche: A location in the farm where fodder legumes are planted.

Opportunity costs: The value of any resource in its best alternative use.

Partial Budget: A partial budget is a technique for assessing the benefits and costs of a practice relative to not using the practice.

Wealth: Access to and control over important resources.

Market access: It refers to the distance between the point of observation (homestead) and some market destination (where public vehicles pass) or combination of destinations.

Cattle management level: Classification based on cattle management indices that are developed by combining different attributes of cattle production variables e.g. type of cattle breed kept, number of livestock units, purchase of cattle feeds, type of cattle rearing structure, use of hired labour, ownership of chaff cutters, selling of milk, spraying of animals and milk production per animal.

CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 LITERATURE REVIEW

2.1.1 Dairy industry in Kenya

Dairy production, which is a major activity in the livestock sub sector of agriculture, is an important source of livelihood for about 600,000 small-scale farmers. The sector contributes approximately 10% to GDP (GoK, 2002). The importance of dairy enterprise in smallholder farms has increased in the 1990s, due to liberalization of the sub-sector (Omore *et al.,* 1999). This coupled with reduced cash crop prices (e.g. coffee) has made smallholder dairy production an important income earner in smallholder farms in Kenya. Liberalization of the sector has also led to emergence of many private enterprises throughout the dairy sector. By 2002, 45 private milk processors had been licensed (GoK, 2002). With liberalization, the volume of milk handled by Kenya Cooperative Creameries (KCC) has declined while that handled by private processors has increased. Therefore the reduced public support has altered milk market structures and potentially the relative prices of inputs and outputs.

Smallholder dairying has thrived on the good agro-climatic conditions in the temperate Kenyan highlands, most of which are located over 1500 meters above sea level. In most cases, production is typically based on close integration of dairy cattle into the mainly maize and or cash crop based farms (Staal *et al.*, 2002). An important element of this system is the use of manure to fertilize food and cash crops, allowing sustained multiple cropping on the smallholdings. Cattle are mainly fed with planted fodder (napier grass) (Mwangi, 2001) and supplemented with concentrate feeds such as grain millings or compounded dairy feeds (Staal *et al.*, 2002).

Despite the contribution of the sector to the economy, high cost of inputs and services has been identified as one of the constraints that livestock farmers face (GoK, 2002). Fodder legumes, especially fast growing leguminous trees e.g. calliandra provide great potential for increasing the incomes of small-scale farmers by alleviating feed problems (Wambugu *et al.,* 2001).

The first calliandra plantings in Embu occurred between 1988 and 1993. Since then, farmers have expanded their plantings from the first planting which averaged 90 shrubs of which 84 survived to 218 by 1995 an increase of over 2.5 times (Franzel *et al.,* 2002). By

1998, the number of shrubs per farmer averaged 311 (Ondieki, 1999). Research on fodder legumes began in Kenya in the 1980s in coast province. The study was done by ILRI and KARI. The National Agroforestry Research Project (NAFRP), a project jointly managed by ICRAF, KARI, and KEFRI in early 1990s, initiated the first on-farm trials in Embu. In 1991, NAFRP scientists tested three fodder species including calliandra to find out farmers' preferred niches.

During 1999-2000, a project implemented through System wide Livestock Program (SLP) of the Consultative Group on International Agricultural Research (CGIAR) helped farmers to plant calliandra across seven districts of central Kenya. This project, implemented by ICRAF, KARI, and ILRI also introduced other fodder legumes including desmodium (Franzel *et al.*, 2002).

2.1.2 Economic benefits of fodder legumes

Farmers have adopted various agroforestry practices because they perceive that these practices can have a significant beneficial effect on their economic security (ICRAF, 1995). Fodder legumes help reduce costs and improve the productivity and profitability of smallholder dairy farmers. According to Franzel *et al.*, (2002), substituting calliandra for purchased dairy meal increases household income by 141 US dollars per cow per year (for the years 1996 to 1998. Legumes have higher nutritive value than grasses, being superior in both protein and mineral content (Roothaert and Franzel, 2001).

Economic benefits of calliandra can be realized in the first year after planting and can produce fodder continuously for more than ten years (Wambugu, 2002). Benefits from the productivity increase attribute of calliandra arise from the fact that with higher milk output, farmers have more milk to consume and sell for extra income. To obtain high economic returns, lactating cows with high milk producing potential may be fed protein rich supplement like fodder legume(s). Fodder legumes are probably profitable only when fed to improved or crossbred dairy animals as indigenous breeds convert only a small percentage of additional feed to increased milk production. (Franzel and Scherr, 2002).

On-farm feeding trials have confirmed the effectiveness of calliandra as both supplement to the basal diet and as a substitute for dairy meal. By using calliandra, Roothaert *et al.*, (2001) and Paterson *et al.*, (1998) noted that a farmer could replace or substitute commercial

concentrates (dairy meal) with positive effects on milk production and profitability; 3 kg of fresh calliandra (1 kg dry) has about the same positive effect on milk production as 1kg of dairy meal (ICRAF, 1996). The response in both cases is about 0.6 kg of milk per cow per day.

There are many examples from tropical world where fodder legumes have had a positive effect on animal production and these are confirmed by experiences in Kenya. In a study in Embu, Franzel *et al.,* (2002) found that the establishment costs (including the cost of seedlings and planting) were 6.58 US dollars per 500 shrubs, which are needed per cow per year. For the second year, harvesting and feeding 2 kg of dry calliandra per day as a supplement throughout the lactating period increases milk production by about 450 kg per year or an increase of about 10% over base milk yield (ICRAF, 1998).

Extra benefits per year after the first year were over 14 times higher than incremental costs, the net benefits per cow per year after year one were 141.68 US dollars. From the analyses, it was found that by using calliandra as a supplement, farmer's annual income increase by about 120-142 US dollars per cow per year, for the years 1996 to 1998 for which economic data were collected (Franzel *et al.*, 2002). Given that an average farmer owned 1.7 cows, calliandra increases farmers income by about US dollars 204 to US dollars 241 per year representing an increase of about 10% in the total household income (Murithi, 1998)

Though calliandra is used mainly as a fodder, farmers have claimed they obtained fuel wood benefits from it in addition to increased milk production and improved animal health (Ondieki, 1999). Others cited soil conservation as a benefit (Franzel *et al.*, 2002). Angima *et al.*, (2002) in a study in central Kenya also noted that combined *calliandra*-napier grass hedge technology significantly reduce both run-off and soil loss. This was important in slopes of 20% or less. Also farmers fed calliandra to a variety of other animals in addition to dairy animals. These were heifers, goats, bulls, and rabbits. The utilization of the seeds produced by calliandra shrubs amongst farmers varied considerably in the same study (Franzel *et al.*, 2002), but 40% of the farmers harvested the seed, 33% gave to others while a negligible proportion (only 2 farmers) sold to other farmers.

Murithi, (1998) noted that the inclusion of calliandra into the farm plans improved profitability of farmers. He further concluded that the demonstration of a positive economic

impact of a technology is one of the factors that influence the adoption of technology by farmers.

A study by Van der Veen, (1993), in western Kenya on economic analysis on farms of alley farming with fodder trees on dairy cows supports the findings of other researchers. By feeding 7 kilograms of calliandra per day as a supplement and given that one hectare of calliandra trees results in 5,450 kgs of fodder leaves, results to an increase of 0.80 litres of milk per cow per day. At the price of Ksh 6.20 per litre, farmers' net benefits will amount to Ksh 3,862 per cow per year (Van der Veen, 1993).

The same study also found that in addition of fodder, other benefits, which were derived from the tree, were fuel wood, though its trade was low as households who have shortage prefer to buy charcoal or kerosene. Other benefits though not quantified in the study include soil erosion control, improvement in soil fertility due to nitrogen fixing aspect of fodder in that crops grow better next to them. Also the animal, which was fed on fodder, was found to be in better condition which resulted in higher fertility by shortening of calving interval.

A study in Zimbabwe by Moyo and Ayuk, (2001) on the costs and benefits of tree fodder among small scale farmers found that farmers who rely on tree fodder as part of their feeding strategy operate in economic terms highly viable small dairy enterprises compared to those relying on other feeding resources. The study also found that, the use of fodder allows for flexibility since adjustments in feeding can easily be made by individual farmers according to seasonal changes in labour availability. This means tree fodder can be used profitably both as a complement and as a substitute for commercial feed.

As with calliandra the benefits of growing desmodium has been demonstrated in a study in Maragua district by Mwangi (2001), where one of the objectives was to document farmers experience with desmodium. In the study higher dry matter content and higher nitrogen content yields were found to be the benefits of the legume. Other additional benefits which turned out to be the most beneficial to farmers was weed suppression by the legume when grown together with napier grass. This benefit was easily observed and quantified by farmers since weeding constitute a major cost in the napier grass fodder system (Mwangi 2001). Hence the saving resulting from weed suppression is attractive to farmers (Mwangi and Wambugu, 2002).

By integrating desmodium into cropping system, spacing is changed from recommended 1 x 1 m to 1 x 2 m with the legumes planted between napier grass rows. This change in spacing reduces labour required to establish one hectare of napier grass from 222 to 111 Man-hours (Mwangi, 2001). Other benefits of napier- legume integration is the increase in carrying capacity of the stock (heifers) from 8.2 heifers per hectare per year to 9.8 heifers per hectare per year and the live weight gain would be 1690 kg per hectare per year from 1280 kg per hectare per year, giving an extra 410 kg per ha per year, live weight, and this would mean an extra Ksh 28,700 per year (at the price of Ksh. 70 per kg live weight) (Mwangi, 2001).

2.1.3 Farmer experimentation

Management of calliandra trees depend on the farmers' objective of planting the trees, that is, whether the trees are grown for fodder, firewood, stakes or seeds (Wambugu, 2002). Fodder trees are managed in order to improve conditions for cultivation of food crops next to them, increase production of leaves for feeding livestock or to grow for seeds. Lay experimentation (farmer innovations) has led to the development of different management practices of fodder trees. Often, this is done without formal research and extension agents (Saad, 2002). Most farmer innovation is as a result of problems faced during daily work (Kibwana, 2000). It has often been noted that experiments that farmer's conduct (farmer innovations) are limited by the number of technological options available to them. Many scientists have observed that farmer innovations are inversely related to the level of contact that farmers have with formal research system (Saad, 2002). The propensity to experiment and try out new ideas may be more pronounced in areas of diversified agriculture and poor extension service (Rhoades and Bebbington, 1991) and are likely to be found in areas where market forces are in transition (i.e. new opportunities are opening up) (Saad, 2002). Extension messages encourage homogeneity instead of encouraging adaptation to diverse conditions (Michael, 2001).

Franzel *et al.*, (2002) in a study in Embu noted that the pruning methods varied among farmers but the common pruning height was 1.0-1.4 metres high. Individual farmers were experimenting on the effect of different cutting heights. Pruning data provides information on preferred cutting management. It also provides guidelines for cutting height in the design of agronomic trials with trees and shrubs (Roothaert and Franzel, 2001). Frequent cutting of

leaves stimulates vigorous growth and hence sustained supply of fodder and improved quality (Wambugu, 2002). Though shears was the recommended pruning equipment, which leaves minimum wounds and promotes fast and health re- growths (Roothaert *et al.*, 2001), some farmers used machetes claiming that the stems were too thick to use shears. Also some broke off the branches by hand primarily to save time (Franzel *et al.*, 2002). Also farmer experimentation was evident on the method of establishment, some used potted seedlings while others used direct seeding. Feed back on farmer innovations has resulted in changes of extension recommendations. For example, farmers in Kandara division of Maragua district conducted their own experiments on soaking calliandra seeds before planting and found that seeds soaked for 48-60 hours had higher germination rate than those soaked for the recommended 24 hours. This has led to extension agents recommending longer soaking hours (Franzel and Scherr, 2002).

In controlling pests, the effectiveness of spraying solution made from tobacco, hot pepper and marigold to control pests were evaluated by farmers. Similarly on their own, farmers were able to determine the best niches for *calliandra*. Farmers planted the fodder on internal and external boundaries, around homesteads and intercropped with napier grass. Through process of small-scale experimentation, farmers can learn to develop and adapt new technologies (Bunch, 1991). Farmer innovation and feedback have played an important role in modifying the extension messages shared with farmers and in identifying second-generation issues for enhancing adoption potential (Franzel *et al.*, 2001).

In his study on farmer innovations on improved fallows using leguminous trees in eastern Zambia, Keil (2001) observed that whether or not an innovation was made by the farmer is not related to the age, gender, or the level of formal education. In the same study, a positive relationship was found between the innovativeness of a farmer and their wealth status. No farmer in the poor stratum had made an innovation concerning improved fallows. Poor farmers cannot afford to take the risk of trying something completely new, which may turn out to be a failure. In contrast, well-off farmers with abundant land resources can take the chance of conducting their own experiments on a small portion of their farms.

Farmer innovations in the case of desmodium are demonstrated in different niches where the fodder was planted. Initially the only niche for the legume that was discussed with the farmers was the napier grass stands. Farmers later planted the legume under coffee, banana

and avocado trees and on soil conservation structures (Mwangi and Wambugu, 2002). Also due to unavailability of planting material (seeds), high cost (desmodium seeds costs approximately Ksh.2000 per kg) and difficulty in handling the seed, an alternative method of establishing the legume through the stem cuttings (vines) was implemented, thus ending the dependency on seeds. This planting and experimentation by farmers would not have been possible if desmodium had to be established from the seed.

It has been noted that the type of experiments that farmers conduct are limited by the small number of technological alternatives or options available to them. This has been the argument fuelling the surge to increase the number of options or potential solutions available to farmers (Saad, 2002). Hence there is need to carefully monitor farmers' own experiments and management practices so that farmer's collective findings can be disseminated widely (Pisanelli *et al.*, 2002).

Though studies have been made on the effect of fodder legumes on livestock (weight gain and even milk production) when used to replace dairy meal or as a supplement in addition of dairy meal, none has incorporated scenarios such as level of cattle management, differential access to markets and gender. In addition, it is very useful to know what farmers see as benefits of the new technology (practice) and what problems they encounter in order to provide feedback to researchers and extension agents for refining their approaches (CIMMYT, 1993).

Similarly, there is need to expand the range of variables used in farmer innovation studies from broad socio-economic, institutional and demographic factors. For example age, gender and education level of the farmer which were mainly used in adoption studies e.g. by Keil (2001). This study will in addition of some conventional variables incorporate variables such as rank and management level of the dairy enterprise, experience with fodder trees and contact with extension agents in farmer innovation.

2.2 THEORETICAL FRAMEWORK.

2.2.1 Theoretical framework: The partial budgeting technique

The basis of farm management analysis techniques is production economics. The principles of production economics clarify "the concepts of costs, output response to inputs and the use of resources to maximize profits and/or minimize costs" (Doll and Orazem,

1984.) Therefore, for the farm-level decision makers seeking to maximize profits the principles of production economics are useful.

Partial budgeting is concerned with evaluating the consequences of changes in farm methods or organizations that affect only part rather than the whole of the farm. Thus, partial budgets are used to evaluate the effect of the farm profit of a proposed change in the way a farm is operated and run. Partial budgeting is most appropriate for evaluating the effects of relatively small changes in farm organization or methods (Anaman, 1988), for example substituting fodder trees for a purchased protein concentrate in dairy enterprise (Franzel *et al.*, 2002). Farmers encounter a number of alternatives relating to the conduct of a particular farm enterprise. Since there are many technical possibilities of production, a farmer must choose the most economical method measured in whatever terms (e.g. physical labour, time, or money) to suit his or her condition (Anaman, 1988). For example a dairy farmer can use fodder trees or commercial concentrates (dairy meal) in milk production. He will need to consider the physical performance of each feed and the cost of each. The principle is this: in substituting one feed for another, the farmer has to be certain that the saving in the feed replaced (dairy meal) is greater than the cost of the feed added (fodder trees).

The principle of substitution has an extremely useful application when farmers are considering the adoption of any new practice (Dillon and Hardaker, 1980). Farmers will consider the costs of changing from one practice to another and the economic benefits resulting from that change (CIMMYT, 1988). Partial budgeting hence provides a convenient way of comparing the profitability of such alternatives. The farmer examines the possible modified plans that he can conceive of and he uses the partial budgeting rule to help choose one of them (Anaman, 1988). If the expected increase in returns from a modified plan is greater than the expected increase in costs, then the farmer may undertake the modified plan.

Economic theory of farm production is based on principle of marginalism indicates that the farmer or producer in general will implement a decision if the marginal (incremental) returns exceeds marginal costs (Anaman, 1988). Economic decisions are then made based on marginal changes in costs and revenues with the aim to maximize profits. Hence the farmer may implement a farm plan if the marginal revenue exceeds the marginal costs.

Since a farmer deals with risky situations, this concept can be made to yield the decision rule that if expected marginal returns are greater than expected marginal costs, then the

decision may be undertaken. The assumption is that the farmer is trying to maximize expected profits. Maximizing profits implies that the farmer is risk neutral and does not care about risks and uncertainty involved in farming. However in most farm situations in Africa or elsewhere, farmers do not only consider expected profits but also the risk and the reliability of achieving these profits in making farm decisions (Anaman, 1988).

Farmers do care about risks and as they attempt to evaluate the net benefits of different outcomes, they usually take risks into account and they take steps to offset it, which contradicts the assumption of maximizing expected profits (Anaman, 1988; CIMMYT, 1988). Farmers attempt to protect themselves against risks or loss of benefits and often avoid choices that subject them to these risks, even though such choices may on average yield higher benefits than less risky choices (CIMMYT, 1988).

Economic theory of production also treats farmers strictly as entrepreneurs or businessmen separating the aspect of economic life from social life, which is not the case in most parts of Africa. Therefore, the economic theory of farm-firm can be described as a reference model, which may be modified and extended to explain the behaviour of farmers under different situations.

The distinctive feature of partial budget analysis is that only factors contributing to changes in the measure of whole-farm performance being considered are included in the budget (Dillon and Hardaker, 1980). Thus, partial budget analysis of the possible use of calliandra and desmodium as a supplement and as a substitute for dairy meal would be carried out by budget analysis by encompassing only performance elements which would be affected by the introduction of calliandra and desmodium by comparing the situation with and without the fodder legumes. This way, the net effect of its introduction on relevant measures of whole-farm performance could be estimated.

The merits of a partial approach to budgeting are considerable. Partial budget analysis is less demanding of data than the whole-farm budgeting. It is not necessary to have information on parts of the farm not affected by the change under review since the performance of these sectors will remain constant. For this reason then, partial budget analysis is generally simpler than whole-farm budget analysis. Also by their nature, partial budgets are typically applicable to a wider range of farm circumstances than is the case with the whole-farm budgets. Moreover, partial budgeting is relatively a simple procedure and can easily be taught to

extension workers, or even the farmer provided they have a minimal level of education (Dillon and Hardaker, 1980).

Partial budgeting is carried out with the assumption that farmers' main concern is profitability rather than issues such as equity. Hence there is lack of understanding of the farmers' objective, which may not be profit maximization. Even though farmers are assumed to behave rationally; however this does not necessarily mean that they are concerned with maximizing the net returns of one given enterprise (Rushton, 1996). Also during tabulation, there is lack of time analysis as all factors are arranged as occurring during the same time period. Finally, conditions under which farmers operate are assumed to be similar.

The first step in partial budgeting is to describe carefully and exactly the changes in farm organization or practices that are being considered; in this case, it is supplementing fodder legumes for dairy meal in milk production. Next, the gains and losses resulting from the specified change need to be listed and quantified.

According to Dillon and Hardaker, (1980), gains can be classified into two categories:

(a) Costs saved. These are costs that would have been incurred under existing system but that would be avoided if the proposed change were to be adopted.

(b) Extra revenue arising out of proposed change should be added.

Losses can also be classified into two categories:

(i) Extra expenses or costs that occur because of the proposed change

(ii) Revenue foregone as a consequence of the changes i.e. any revenue which would be received under the present system, but which would no longer be received if the change under review were to be implemented

The change in total farm profit associated with the budget change can easily be calculated quite simply as total gains minus total losses. If total gains are greater than total losses, then the budget obviously will indicate that the proposed change is profitable. If the converse is true, the indication that the change is not profitable. Of course this assessment of the change in farm profit is contingent upon the correctness of the technical and financial data used in the budget. As the success of partial budgets depends on prediction accuracy which depends on the accuracy of information and estimates it contains. The manager therefore needs to collect factual data about the proposed change and provide reasonable estimates of such item as future prices, yields and gains. Factual information includes current costs of factors of

production, cost of capital, current commodity prices and other items pertinent to the particular decision.

In partial budget analysis, it is not always possible to quantify and include in the budget all the factors bearing on the decision as to whether or not a proposed change should be implemented. Hence, it is necessary to list any important non-pecuniary factors bearing on the choice. These factors include the degree of risk associated with the change, the implication of the proposal for the farmer and his family in terms of amount and nature of work to be done and the management skill required to operate successfully the proposed new farm system. Any prerequisites for the successful implementation of the proposed change should be noted e.g. additional capital (Dillon and Hardaker, 1980).

When both pecuniary and non-pecuniary aspects of the proposed change have been set down, it should be possible to make recommendations on which the farmer(s) to whom the partial budget is relevant may act. Results of partial budget analysis can be used to answer policy maker's questions about the effects on farm output, income and resource use of some actual/proposed policy changes.

2.2.2 Conceptual framework: Farmer innovation

Based on the review of literature and own consideration, variables in Table 1 are hypothesized to influence farmer innovation, which is defined as activities that farmers engage in independently of formal research sector.

Table 1: Hypothesized determinants of farmer innovation and expected sign of relationships

Explanatory variable (X)	Expected sign of relationship with innovation (Y)
X1: Age of farmer	Positive
X2: Gender	Positive for female; Negative for male -headed farms
X3: Level of education	Positive
X4: Experience with technology	Positive
X5: Wealth level	Positive
X6: Extension contact	Negative
X7: Rank of dairy enterprise	Positive
X8: Management level of dairy enterprise	Positive

The following relationships among explanatory variables, is hypothesized.

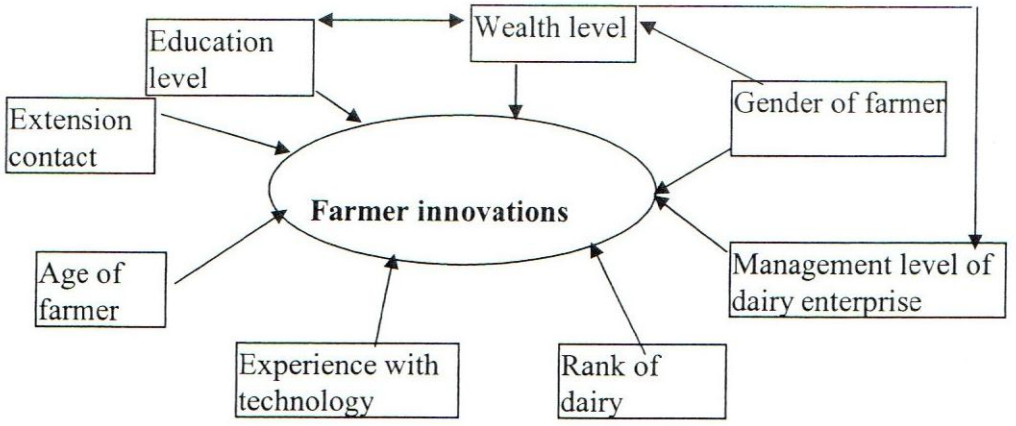


Figure 1: Hypothesized determinants of farmer innovation and relationship among them

The conceptual framework (Figure 1) shows that farmer innovation is the dependent variable, as influenced by the independent variables namely, age of the farmer, experience with the technology, rank of dairy enterprise, gender of the farmer, educational level, wealth levels[1], contact with extension agents and management level of dairy enterprise.

The negative sign (-) (Table 1) implies that there is a negative relationship/ influence between the variables. This means that the higher the status of the independent variable, the lower the dependent variable and vice versa. The positive sign (+) implies that there is a positive relationship between the two variables. This means that the higher is the status of the independent variable in the relationship, the higher the dependent variable and vice versa.

[1] Wealth is defined as access to and control over important resources e.g. ownership of grade cattle and types of housing (farmers').

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study area

The study was conducted in Embu District from February to May 2003. Selection of the study area was based on the following reasons, one, the district falls within the National Agroforestry Research Project (NAFRP) mandate area for applied research and transfer of the improved fodder trees. It is also where on-farm trials and dissemination activities on fodder trees have been conducted with farmers since the 1990s, hence have more experience concerning fodder legumes i.e. it is an area where farmers with lots of experience are found. Secondly, improved small- holder dairying is a major component of land-use system in the district.

Embu district is one of the 12 administrative districts of Eastern province of Kenya. It is bordered by Mbeere district to the east and southeast, Kirinyaga district to the to the west, and Tharaka-Nithi district to the north. It lies approximately 0° 8'' and 0° 35'' south and 37° 19'' and 37^{0} 42'' east. The district covers an area of 708 square kilometres and is subdivided into 6 administrative divisions namely Manyatta, Runyenjes, Nembure, Kyeni, Central and mount Kenya Forest. Runyenjes division is the largest with an area of about 148 square kilometres, followed by Manyatta, Kyeni and Nembure. Central division is the smallest of all covering an area of 71 Square kilometres.

Population density is high ranging from 450 to 700 persons per square km. The population density is higher in Central division than any other division, due to its small size and its status as the provincial and district head quarters. Out of the districts total area of 708 square kilometres, about 70% is arable land while the forests cover the remaining 30% (GoK, 2002a). The main crops in the study area are coffee, produced for cash, and maize and beans produced for food. Because of limited land the fields are cropped continuously. Livestock production activities are a significant supplementary source of incomes for people of Embu district, with cattle and goats being the most important type of livestock kept. Most parts of the district have more or less equal potential for livestock activities especially dairying due to the districts favourable climatic conditions. The main feed source for dairy cows is napier grass supplemented during the dry season with crop residues such as maize and bean stover, banana leaves and commercial concentrates. Since napier grass has low protein content,

commercial supplements are recommended to ensure adequate nutrition to the cows. However as these feeds are expensive, farmers often feed less than what is recommended 4 kg of dairy meal per cow per day (Murithi, 1998).

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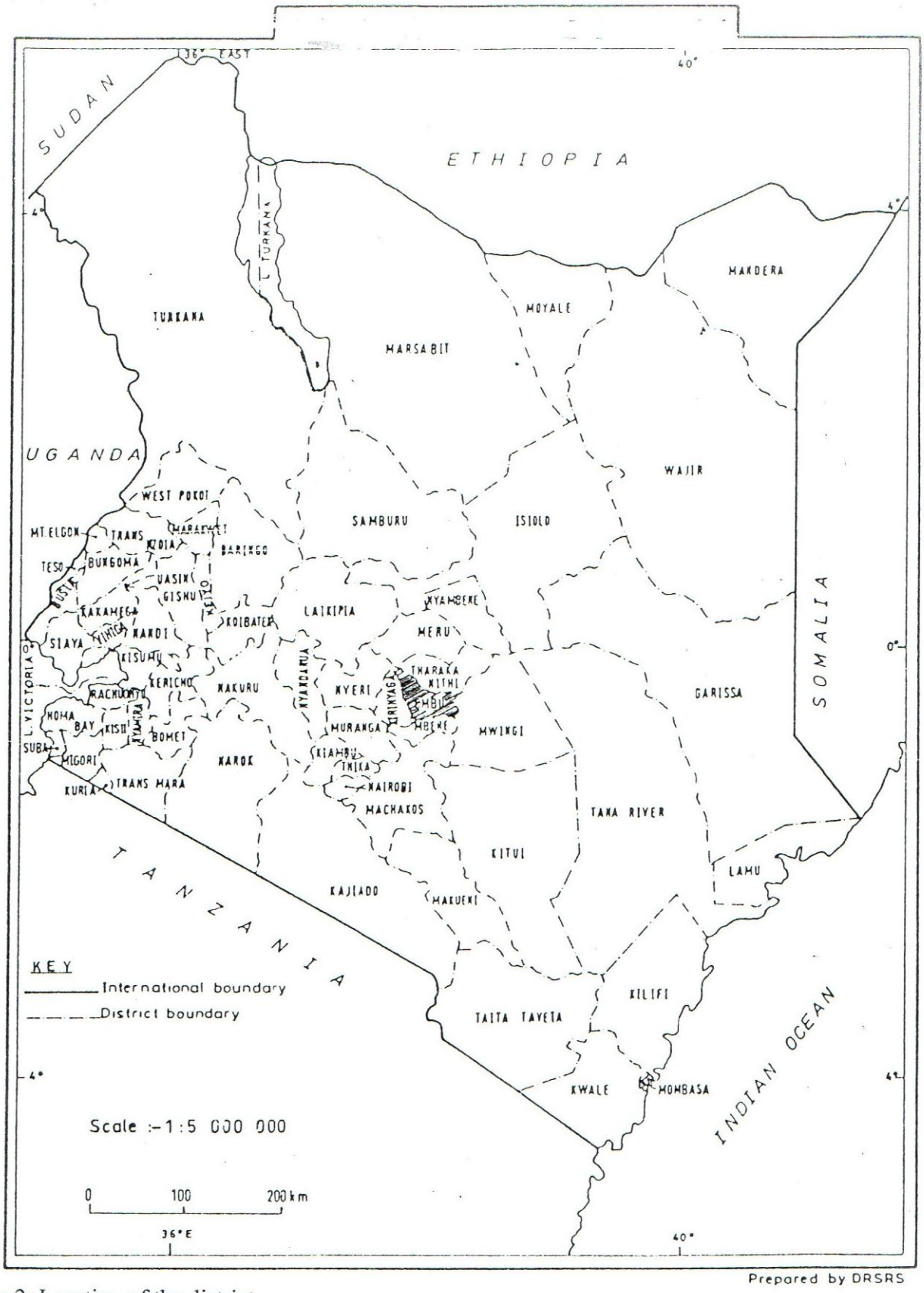


Figure 2: Location of the district

3.2 Sources of data

Data collection involved 60 farmers who were randomly selected as described in the next section. The farmers consisted of only those who have adopted the legumes. Formal personal interviews using structured questionnaire (Appendix 2) was used to collect primary data from farmers who have adopted calliandra and/or desmodium fodder legumes in order to develop an understanding of the performance of these fodder legumes from farmers' point of view. Information on farm and household characteristics was also collected using the structured questionnaire.

A checklist of activities and inputs (Appendix 1) was used to collect data, which were used to determine the costs associated with establishment and management of fodder seedlings (economics of seedlings production).

Personal interviews were supplemented with field visits and farm observations to determine the farmer's innovations and current uses of fodder shrubs. In order to determine the amount of fodder and dairy meal given to the animal, weighing was done. Cattle weights were determined by measuring the chest girth of the animal using the tailors' tape and checking with corresponding weights (Appendix 3). The researcher conducted all interviews.

Secondary data were used in the description of the study area including the farming system, and fodder legumes technologies. The sources of secondary data included publications by research institutions, works by other researchers and government publications. Secondary data were mainly obtained from libraries and other resource centres.

3.3 Sampling procedure

The sample frame used in the study, consisted of farmers who received planting materials of fodder legumes from the National Agroforestry Research Project (NAFRP) and the National Dairy Development Project (NDDP) in the early 1990s. A second list was derived compiled, with assistance of extension staff, comprising farmers with desmodium. Random sampling method was used to select 56 calliandra and 24 desmodium adopted farmers from the list who had the legumes on their farms. Twenty of the 24- desmodium adopted farmers also had calliandra. Since the population was homogenous consisting only of adopters, the sample size consisting of 60 farmers was found to be suitable.

The 20 farmers with the highest number of calliandra trees were selected for determination of net benefits of calliandra. We chose farmers with the high numbers because farmers with low numbers were not likely to discern impact on milk production. Multi stage sampling was used to select desmodium farmers for determination of net benefits of the legume. In this procedure, the first stage involved selection of twenty- four farmers having desmodium from the sample mentioned above. Then random sampling method was used to select 20 farmers for determining its net benefits.

A list of farmers/groups having fodder legumes nurseries was established. Ten nurseries were identified and all were interviewed for determination of costs associated with establishment of calliandra seedlings.

3.4 Data analysis

Most of the data analysis was carried out using the SPSS[2] and EXCEL software packages. In order to determine the net benefits of fodder legumes (economic analysis) partial budgets were used. As this regards an economic analysis from farmer's point of view, we incorporated the costs and benefits associated with fodder legumes i.e. extra costs and benefits of using fodder legumes as a supplement in milk production. Partial budgets are appropriate for practices that have less or limited impacts on the costs and returns of an enterprise.

The independent samples t-test was applied to detect differences in the mean of one variable between two groups of respondents. The difference between net benefits of different cattle management levels and market access was compared by the analysis of variance (F-test). Relationship between two interval variables was analysed using Pearson correlation coefficient, while the Chi-square test was employed to identify the differences in the distribution of the nominal or ordinal variables between different groups of respondents.

Descriptive statistics were also used. The logit model was used to determine the influence of farm and household characteristics on innovation.

[2] SPSS - Statistical Package for Social Sciences, version 10.0.

3.4.1 Analytical model

3.4.1.1 The logit model

The decision to innovate[3] or not is a binary decision which is represented as a qualitative variable whose range is actually limited as it can only take one of two values; 1 or 0 (innovate or not). Farmers' decision to innovate can only be analysed using binary choice models, hence a logit model, a commonly used method in adoption literature was used to determine the association between farm and certain household characteristics and farmer innovation.

The model was chosen because it is easy to use from computational point of view (Mukras, 1993), the probability of individual selecting a given alternative is easily expressed and a likelihood function can be formed and maximised in a straight- forward manner (Kennedy, 1992).

The model is specified as follows:

$$E(Yi)=P(Yi)=e^{\alpha+\beta xi}/1+e^{\alpha+\beta xi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where:

P = Probability of the ith individual (farmer) with xi characteristics or attributes falling into one of the dependent variables classes, E (Yi) = P (Yi) = 1, Yi = 1 if the individual farmer innovates and Yi = 0 if the individual farmer does not innovate.

x = vector characteristics/attributes associated with individual i.e. values of independent variables

β = vector of estimated coefficients

α = Constant

e = natural log (ln)

Dependent variable

The dependent variable (Yi) in the model is whether or not an innovation is undertaken or carried out by the farmer. A qualitative variable innovate is 1 if the farmer innovates and 0 if he does not.

Independent variables

Independent variables for the econometric model for this study which were selected based on review of literature are as follows: age, gender, education level, experience with the technology, wealth levels, extension, rank of dairy enterprise and management level of dairy enterprise. Independent variables and their justification are discussed below.

Age

Data on age (in years) was collected as a continuous variable. Age was hypothesized to be positively related with the decision to innovate. Young farmers are unlikely to innovate. Older farmers may have more authority that would allow them more possibilities for trying something new.

Education

Data on education was included in the model as a continuous variable. Years of schooling were used to measure the level of education of farm manager. By hypothesis, education level was assumed to be positively related to decision to innovate. Educated farmers may have better understanding of the environmental benefits and other merits of having fodder legumes. Education increases farmers' capacity to innovate.

Gender

For female -headed households, it was assumed to be positively related to decision to innovate, as they are the ones who are close to livestock as compared to male-headed household. They are normally responsible for finding all organic feed resources; hence provide most of the labour for African food production (Quisumbing *et al.,* 1995 cited by Franzel, 1999).

Experience with technology (fodder legume)

Number of years after planting (experience with the technology) was also included in the model as a continuous variable. Good knowledge of the technology will most likely lead to more innovation. The more the length of time a farmer has been using fodder legumes,

[3] Farmer innovations are incremental improvement on a standard practice

chances are that he/she will innovate. Farmers with good experience are more induced to innovate. By hypothesis, farmers' experience is positively related to innovation.

Wealth Levels

Resources endowment may influence innovation. A wealthy farmer has resources like land, labour and capital and chances are that he/she will innovate as he can take the risk of trying new ideas. Wealthy farmers may be less risk averse, have more access to information, have a lower discount rate and longer- term planning horizon (Hoekstra, 1985, CIMMYT, 1993)

Extension (contact with extension agents)

Number of times per year was used to determine extension contacts. Often, extension agents carry out demonstrations where farmers can learn. It was hypothesized that contact with extension agent would not influence farmers to innovate. As the farmer will only be doing what is recommended. It is assumed that farmers with poor extension service experiment or try out new ideas (Rhoades and Bebbington, 1991).

Rank of dairy enterprise

The more important the enterprise, the more likely the farmer will innovate. A farmer whose major enterprise is dairying will be trying to innovate especially on the uses and management of the legumes so as to see the impacts, as positive results will make the farmer innovate more.

Management level of dairy enterprise

Farmers on high-level cattle management are expected to be experimenters than those on low management.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Characteristics of farmers

4.1.1 House hold characteristics

The age of the farm manager (a person in charge of making major day to day farming decision) averaged 55.9 years (s.d=11.77). Majority (66%) of them were over 51 years of age (Table 2) and this reflects the fact that farming was generally carried out by relatively old people. Twenty two percent were between 41 and 50 years. Only two percent were below 30 years old. The reason might be that, most farmers were selected from an old farmers' list (sample frame), which was prepared during the introduction of the legumes in the area. Secondly the study focused only on experienced farmers.

Table 2: Age class distributions of the farmers

Age category (years)	Percentage
20 – 30 years	2
31 – 40 years	10
41 – 50 years	22
Over 51 years	66
Total	100

The average level of education of the sampled farmers was 6.8 years (s.d =4.35). Only 37% of them had attained twelve years of education, while 13% had no formal education (Table 3).

Table 3: Years of formal education of farmers

Educational level	Frequency	Percentage
None	8	13
1-8	29	48
9-12	22	37
>12	1	2
Total	60	100

On 55% of the selected farms, the husband did the management. Others were wife (43%) and son (2%). Therefore the percentage of farms that were male managed was 57%.

The proportion of female managed farms obtained in this study was higher than that reported by Wanyoike (2001) which was 22 percent. Categorisation of farmers was based on the person who was responsible for making major day-to-day farming decisions.

Wealth ranking is a method of categorising farm households based on differences in wealth. The wealth level was assessed based on indicators, which had been identified earlier by Murithi *et al.*, (2000) using participatory wealth ranking exercise. Two important wealth indicators from Murithi's work (2000) were selected and used in determination of selected farmers' wealth status. The wealth indicators were the ownership of grade cattle and type of housing (farmers'). Wealth ranking ranged from most wealthy to less wealthy. According to Guinand, (1996) selection should be based on the easiness of data collection and their importance within the land use system as perceived by the farmer. Farmers' wealth status was calculated after the questionnaire had been filled. Each wealth indicator was compared with the indicators from the wealth category list for the area (Murithi *et al.,* 2000) (Table 4). The wealth category the surveyed farmer fitted was then calculated by adding all the wealth category points for each of the collected wealth indicators and dividing them by the number of wealth indicators evaluated. The formula used was as follows:

$$Fwc = \frac{Twp}{Twi} \qquad (2)$$

Where

Fwc=Farmers' wealth category (1=most wealthy; 2=medium wealthy; 3=less wealthy).

Twp = Total wealth category points (e.g. 2, 3, 4 and 6).

Twi = Number of evaluated wealth indicators (in this case, they are only 2).

Table 4: Wealth ranking table

Indicator	1=Most wealthy	2 = Medium wealthy	3 = Less wealthy
1. Grade cattle	More than two	One to two animals	No grade cattle
2. Type of housing	Stone walled	Timber walled	Grass thatched /mud walled

Source: Adapted from Murithi *et al.,* (2000).

The classification (Table 5), shows that bulk (60%) of the selected farmers were medium wealthy, 35% are rich, while only 5% are less wealthy. This is consistent with findings by Ondieki, (1999), where majority of the farmers were also in these two categories. The reason

may be due to the fact that in both studies, same sample frame was used which was based on the list of adopters drawn up by extension staff.

Table 5: Distribution of farmers according to wealth categories

Wealth category	Percentage
High (most wealthy)	35
Medium wealthy	60
Less wealthy	5
Total	100

4.1.2 Farm characteristics

All farmers owned at least a plot where the homestead was located, while 21% owned other plots away from one with the homestead. Most information sought during interview referred to where homestead was located since this was where most of the farming activities were carried out. Homestead farm size averaged 1.48 hectares (mean SD=0.76); while the mean for other plots owned away from the homestead was 0.71 hectares (mean SD=0.82), (N = 13). 0.20 hectares was the minimum size of land owned at the homestead and the maximum was 3.04 ha. For other plots, the minimum size was 0.5 hectares, while the maximum was 2.83 hectares. The total land owned by the sampled farmers averaged 1.64 hectares (mean SD=0.95) (Table 6). This was higher than for average farmers; Wanyoike (2001) who selected a random sample of farmers found the average farm size to be 1.09 hectares.

Table 6: Farm sizes in hectares

Measure	Homestead farm size (N=60)	Other plots (N =13)	Total farm size
Mean	1.48	0.71	1.64
Std deviation	0.76	0.82	0.95
Minimum	0.20	0.50	0.20
Maximum	3.04	2.83	4.86

Half of the farmers owned between one to two hectares of land, with only 9% owning more than 3 ha (Table 7).

Table 7: Distribution of farmers according to total farm owned

Farm size (ha)	Percentage
0-1 hectares	23
1-2 hectares	50
2-3 hectares	18
More than 3 ha	9
Total	100

Market-oriented dairy systems are heavily dependent on infrastructure because of milk's perishability. Generally, the concept of market access combines several elements: (1) distance between the point of observation and some market destination or combination of destinations, (2) the utility of the market destinations, based on their supply or demand attributes, and (3) the impedance level or the quality of the route in terms of relative ease of movement of goods, services, people and perhaps even information (Staal *et al.,* 2002). Combined at the point of observation, these three elements condition prices observed at that point for inputs, outputs and services, their availability, and even their quality.

In this study, the point of observation was taken to be the homestead (farm) and the market destination is the main road where public vehicles pass, where milk buyers collect milk.

Based on the distance between the point of observation (homestead) and some market destination (main road- where public service vehicles pass), the average distance was 1.44 kilometres, (mean SD =1.17). Thirty eight percent of the farmers were within the distance of one to two kilometres to the main road, with 30% being one kilometre away from the road. Generally, 68% of the farmers were within the range of zero to two kilometres (Table 8).

Table 8: Distribution of farmers according to distance to the main road from the farm

Distance in kilometres	Percentage
0-1 kilometres	30
1-2 kilometres	38
2-3 kilometres	20
3-4 kilometres	4
More than 4 kilometres	8
Total	100

Extension staff had not visited 43% of the farmers within the preceding year. Only 15% of them had been visited once, while 10% each had been visited twice and thrice. Twelve percent had been visited more than four times per year (Table 9).

Table 9: Frequency of extension agent contacts with farmers per year

No. of extension contacts per year	Percentage
Never	43
Once	15
Twice	10
Thrice	10
Four	10
More than four	12
Total	100

Farmers were involved in a wide range of enterprises, which ranged from food to cash. Delineation of farm enterprises as either for cash generation or food was not done as it was not straight forward for some enterprises e.g. cattle, maize or bananas have dual roles depending on farmers' needs. The enterprises considered important by farmers (in terms of cash and food generation), and the way farmers ranked them is shown in Table 10.

Table10: Farm enterprises by rank

Enterprise	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	% reporting
Maize	3.3	11.7	20	31.7	6.7	73.3
Coffee	3.3	31.7	25	18.3	1.7	80
Tea	15	10	1.7	1.7	-	28.3
Dairy	50	16.7	18.3	1.7	-	86.7
Poultry	-	-	5	3.3	1.7	10
Fruits	11.7	15	20	8.3	5	61.7
Macadamia	15	5	5	1.7	3.3	30
Dairy goats	1.7	5	-	1.7	3.3	11.7
Vegetables	-	3.3	1.7	5	-	10
Trees (Grivellia)	-	-	-	-	1.7	1.7
Climbing beans	-	1.7	-	-	-	1.7
Potatoes	-	-	1.7	1.7	-	3.4

The most frequently mentioned enterprises to appear in the five most important categories were in order of importance dairy, coffee, maize and fruits. Fifty percent ranked dairy as the most important enterprise. Coffee, dairy and fruits (which include bananas and avocadoes) were ranked second most important enterprises by 32%, 17% and 15% of the

farmers in that order respectively. Twenty-five percent ranked coffee as the third most important enterprise while maize and fruits each ranked third by 20%. Maize, coffee and fruits were ranked as the fourth most important enterprise by 32%, 18% and 8% in that order respectively. Maize and fruits were also ranked as the fifth most important enterprises by 7% and 5% respectively.

4.2 Livestock production

Nearly all (93%) farmers kept cattle with the highest proportion (87%) keeping dairy cows, averaging 1.73 (mean SD =0.91) per farm. Sixty percent of the farmers owned one or two cows. Most (98%) of them kept either pure/crossbred animals, which were mainly reared in an enclosure (zero grazing units) (96%), where they were fed and watered in contrast to open fields. Forty seven percent of the farmers kept heifers, 33% had mature male (bulls), and 47% had calves on their farms. The maximum number of cows and heifers owned was 4 for both while it was 2 and 3 for males and calves respectively (Table 11). Therefore keeping of dairy animals (cows) was common among the sampled farmers implying that it is the main activity (section 4.1.2).

Table 11: Mean number of cattle owned in various age and sex categories

Category	Mean	Std deviation	Maximum	farmers owning
Cows	1.73	0.91	4.00	53(87)
Heifers	1.25	0.64	4.00	28(47)
Mature males	1.20	0.41	2.00	20(33)
Calves	1.28	0.53	3.00	28(47)
Total cattle	3.30	1.75	9.00	56(93)

Figures in parenthesis are percentages

Other types of livestock kept included sheep by (17%), goats (which included dairy and other types of goats) (55%), poultry (72%) and rabbits (13%) of the farmers.

Majority (87%) of the farmers indicated that they produced milk on the farm at the time of interview (i.e. they had lactating cows) and the mean milk output was 12.59 kilograms (mean SD =11.03), (N=53). The mean milk yield per cow per day was 8.50 kilograms. The milk yield per cow was calculated by dividing total milk output by the number of lactating cows.

Most (77%) of the farmers sold milk within the preceding 12 months i.e. from March/April 2002 to the same period the following year. Farmers were asked to give the highest and the lowest prices of milk during the year. The mean lowest price was Ksh 13.40 (Mean SD =2.43) per kilogram and the mean highest price was Ksh 15.40 (mean SD=2.60) per kilogram. Lowest milk prices were experienced during the months between May and December (78%), which is usually the rainy season. The highest milk prices were experienced during the months of January to April (82%), which was the driest season in the area. The high prices may be attributed to low supply of milk (production). This might be due to scarcity of feeds during this time of the year. During the period of survey (March – May 2003), only 68% of the farmers were selling milk. The average price of Ksh 14.35 (mean SD= 2.46) per farm household.

4.2.1 Classification of cattle management levels

The variables, which were used to classify farmers according to level of cattle management, were based on different attributes of cattle production as proposed by (Murithi, 1998) and which were considered to influence cattle production in the farming system. These were:

1. Type of breeds kept.
2. Purchase of cattle feeds by farmers.
3. Whether farmers used hired labour for cattle production activities.
4. Ownership of chaff cutter.
5. Whether farmers sold any milk.
6. Type of cattle rearing structure.
7. The number of livestock units.

In addition, milk production per livestock unit and ownership of sprayer or dipping of livestock, which is important in control of tick-borne diseases, were also considered. Attributes of a single variable are insufficient in determining the category in which a particular farmer belongs. The reasons for selection of these attributes are explained below.

Type of cattle breeds kept

The type of breed is used as an indicator of genetic potential of the animal in terms of milk production. Analysis of breeds kept by farmers shows that nearly all (98%) farmers kept either pure/cross breed cattle. Only 2% of them kept local breeds. Identification of the breeds was based on the knowledge of the farmer and where necessary visual assessment was employed.

Purchase of cattle feeds

The ability and willingness to buy commercial feeds for cattle by the farmer was used as an indicator of the importance the farmer placed on cattle production. It was assumed that those farmers willing to use money to buy feeds for the cattle placed a higher importance on cattle than those who did not buy any feeds. Dairy meal and bran were common commercial feeds purchased by the farmers. Thirty seven percent of the farmers used dairy meal while 53% used bran. It was also assumed that those who bought feeds for their cattle were on higher level of cattle management. From the study, it was found that 80% of the farmers used commercial feeds, while 20% did not use any commercial feed.

Use of hired labour

The ability of the farmer to hire labour was considered to be a reflection of the importance of the cattle enterprise to the farmer. It was assumed that farmers who hired labour were in better position to attain a higher level of management since management activities can be performed on time. Fifty two percent of the farmers used hired labour (either casual or permanent) for cattle production activities. Forty eight percent of the farmers did not use hired labour.

***Ownership of chaff-cutter*:**

Chaff-cutters are used for chopping fodder into small pieces so that they can be eaten easily by animals and with less wastage. Since chaff-cutters are expensive and hence those farmers who owned them were likely to have invested more in cattle production than those who did not have them. It was assumed that those farmers with chaff-cutters placed a high value on their cattle enterprise and hence had a higher level of cattle management. From the study it was found that only 36% of farmers owned chaff cutters, while 64% did not own it.

The small percentage of farmers owning the chaff cutter may be due to cost associated with it.

Whether farmers' sold any milk

The ability to sell milk was an indication that such farmer was able to produce enough milk for home consumption and had extra or surplus for sale. This could be an indication of high production and management levels. Most (82%) of the farmers sold milk during the last one year, while only 18% didn't.

Cattle rearing structure

These were enclosures where livestock were kept. They could be improved with concrete floor, roofed, have water \feed troughs, divided into cubicles, had calf pen, dung or manure drain into pit or napier grass plot or could be unimproved which were simple, temporary and wooden enclosures which were neither roofed or had concrete floors, no secluded sleeping place but the floor was covered with mud, dung, and feed remains. The feeds were given in troughs with the remains thrown into cattle pen or shed. Seventy three percent of the farmers housed their livestock in enclosures, which were improved. The rest, 27% did not have any structure (used tethering), or used the unimproved types.

Cattle units

The number of cattle owned could be used as a proxy for the importance farmers placed on the cattle enterprise with the assumption that those farmers who owned many animals placed more value on their cattle enterprise than those with fewer animals. According to Upton (1993), the number of livestock owned is considered to be unsatisfactory measure of input use because of variations in age and size. The estimation of productive efficiency of livestock requires that the total output produced should be related to the level of input used hence a more appropriate measure was cattle unit, which is based on food consumption requirements.

Because of variation in sizes, weights were found to be appropriate in determining cattle units rather than using the age and sex. Cattle weights were estimated using a tailor's tape where the chest girth of the animal is measured then checked against corresponding weight

(Appendix 3). In order to determine Cattle units, the weight of the animal was checked against exchange ratios proposed by Upton (1993) (Appendix 4).

Cattle units a farmer owned was thus calculated as:

$$Cu = \sum_{i=1}^{n} (N_i * Cf_i) \quad \text{.....(3)}$$

Where:

Cu = Cattle Units

N = Number of the animals owned by the farmer

Cf = Conversion factor.

i = (1,2,3.....n) number of animals owned by the farmer.

Using the above conversion factors, the number of cattle units per farm ranged from 1.0 to 8.26 with the mean of 3.44 (mean SD=1.86). The number of cattle livestock units on the farm was used as a reflection of the importance of the cattle enterprise to the farmer. The distribution of farmers according to categories of the number of cattle units showed that 52% of them were having between 1.5 to 3 cattle units (Table 12).

Table 12: Distribution of farmers according to categories of number of cattle units

Cattle unit category	Percentage
Less than 1.5	21
1.5 – 3	52
More than 3	27
Total	100

Ownership of sprayer or dipping of livestock

Those farmers who sprayed or dipped their livestock to control tick-borne diseases placed a high value on their cattle enterprise and would be on higher level of cattle management. Most (87%) of the farmers reported that they sprayed their livestock, while 13% did not.

Milk production per animal

It was assumed that the higher the milk yields per cow, the higher the level of management. The yield per cow was estimated based on the average milk per cow of the sampled farmers regardless of stages of lactation. The mean milk production per milking cow per day was 8.50 kilograms with a standard deviation of 4.7. This average was higher than 6 kilograms per

milking cow reported by Wanyoike (2001). Most (61%) of the farmers produced less than 8.90 kilograms of milk per animal, while 39% produced more than average milk per animal (Table 13).

Table 13: Distribution of farmers according to milk production per animal

Milk per livestock unit range	Percentage
1 - 4.9 kilograms	19
5 - 8.9 kilograms	42
9 - 12.9 kilograms	17
13 - 16.9 kilograms	15
More than 17 kilograms	7
Total	100

4.2.2 Calculation of cattle management index

Cattle management index was next calculated using the above-identified attributes. The attributes were first scored as shown in Table 14. The scores were ordinal measures, which showed the status as far as a particular variable was concerned. Ordinal measures indicate the rank of a given attribute and do not imply that the intervals between the ranks are equal. No weighting was done, as all variables were assumed to equally important.

Table 14: Scores of the various cattle production variables

Variable	Scores and attributes
Breed type	1= has pure breed: 2= Owns cross breed 3 =zebu
Purchase of feed	1= Buys feeds: 2= Do not buy feeds
Hiring labour	1=Uses hired labour: 2=Do not use hired labour.
Type of cattle structure owned	1= Improved: 2= Unimproved structure
Ownership of chaff-cutter	1= Owns chaff-cutter: 2= Do not own chaff cutter
Sale of milk	1= Sells milk: 2= Do not sell milk
Sprayer ownership \Dipping	1= Sprayer ownership \Dipping: 2= Do not own a sprayer \no dipping
Milk yield per livestock unit	1 = More than average yield per livestock unit : 2 = less than average yield per livestock unit
Number of livestock units	1= More than 3, 2= between 1.5-3, 3= Less than 1.5

Source: Adapted from Murithi, (1998).

Cattle management index was calculated by summing up the different scores of the different attributes for the variables. The farmers at the lower index were at higher cattle management level than those with higher index. The index was calculated using the following formula:

$Mi = Bt + Bf + Hl + Tcs + Occ + Sm + Cu + So + Ylu$.....(4)

Where:

Mi = Cattle management index

Bt = Breed type category

Bf = Buying of feeds

Hl = Hiring of labour

Tcs = Type of cattle structure

Occ= Ownership of chaff-cutter

Sm = Selling of milk

Cu = Cattle livestock units

So = Sprayer ownership \dipping of animals

Ylu = Milk production per livestock unit

The indices were then grouped into three categories based on the distribution of farmers as shown below:

High level = Index 9 to index 12

Medium level = Index 13 to index 16

Low level = Index 17 to index 20.

4.2.3 Cattle management levels

The sample of farmers who had cattle was classified into three categories based on cattle management indices that were developed by combining different attributes of cattle production variables as previously discussed. These aspects represent different aspects of management and investment in cattle production. Table 15 shows that 50% of the farmers were on high level of cattle management, while forty-three percent were on medium management level. Only 7% of the farmers were on lower level.

Table 15: Distribution of farmers according to cattle management level

Cattle management index	Percentage
High level	50
Medium level	43
Low level	7
Total	100

4.2.4 Constraints to livestock production

Farmers cited several constraints as impediment to the expansion of the enterprise (livestock). Lack of capital to buy commercial feeds and cows especially, exotic breeds was reported by 43% of the farmers as the most important constraint. Other constraints mentioned were shortage of land for fodder (30%), lack of milk market (18%) and lack of labour (8%). Therefore adoption of fodder legumes will address the problem of lack of capital for buying commercial feeds like dairy meal through provision of home produced substitutes.

4.3 Fodder legumes in Embu

4.3.1 Fodder plantings

Agroforestry systems involving fodder legumes like calliandra and desmodium appear to be a promising option to improve fodder situation in Embu district given the small land holdings, which average 1.09 hectares (Wanyoike, 2001). As the size of land holdings keeps on declining due to sub divisions, most livestock feeds will have to come from planted forages and the cropped land. Therefore the introduction of fodder legumes, calliandra and desmodium, as a potentially rich protein supplement for increased milk production, the focus has to be on integrating them into existing cropping system other than allocating land to them.

The majority (60%) of the selected farmers had one type of fodder legume calliandra (60%) and desmodium (7%) on their farms. Thirty three percent of the farmers had both calliandra and desmodium (Table 16). Therefore calliandra was the most commonly distributed fodder species planted by 93% of the farmers, it was also reported as the most preferred species in the area, (Place, 1998). Desmodium was planted by 40% of the farmers.

Table 16: Distribution of farmers as per fodder type

Fodder type	Percentage
Calliandra only	60
Calliandra and desmodium	33
Desmodium only	7
Total	100

Fifty seven percent of the farmers had first planted their calliandra trees within 11 to 15 years ago. The average number of years since they first planted the legume was 11.01 years (mean SD =4.98). The minimum number of years was 2 and the maximum was 18 years. Forty

six percent of the farmers had planted desmodium within 1 to 5 years ago, 7.5 (mean SD =5.77) was the average number of years since they planted the legume (Table 17). This implied that calliandra was generally planted earlier than desmodium in the area.

Table 17: Fodder legume planting experience

Years	Calliandra Percentage	Desmodium Percentage
1 – 5 years ago	23	46
6 – 10 years ago	16	21
11 – 15 years ago	57	29
More than 15 years ago	4	4
Total	100	100

The average number of calliandra trees per farm was 607 (mean SD. = 884; median = 300) while the average area of desmodium planted was 846 square metres (mean SD = 1061). Twenty three percent of the farms had less than 100 calliandra trees with the similar number having more than 500 trees (Table 18). According to Franzel *et al.,* (2002), the number of calliandra trees which are needed per cow per year are 500. Therefore, majority (77%) of the farmers had less than what is recommended.

Table 18: Distribution of respondents by the number of calliandra treesper farm

Number of trees	Percentage
Less than 100 trees	23.2
101 –200 trees	16.1
201-300 trees	16.7
301-400 trees	5
401-500 trees	13.3
More than 501 trees	23.2
Total	100

4.3.2 Management of fodder legumes

According to Wambugu, (2002), management of fodder legumes depends on the farmers' objective for planting them, i.e. if they are for fodder, firewood, stakes or seeds. All the sampled farmers were using the legumes for feeding livestock (either their own or sold the fodder to others) and hence most practices done by the farmers were primarily to increase production of leaves.

The niches where farmers planted calliandra varied considerably with most farmers planting it on internal (homestead) boundaries (59% of the farms) and external boundaries (21%). Others intercropped it with napier grass on contours (18%) or intercropped with other crops (with maize, bananas; both 7%; maize/banana, beans and avocadoes; which was 2% each. Other niches were, intercropping calliandra with desmodium on internal and external boundaries, reported by 4% of the farmers and as pure stand fodder bank (2%). The common niches for desmodium are integration with napier grass either on contours or on fodder banks, as cited by 38% and 46% farmers respectively. Other niches where farmers have planted desmodium were as pure stand (4%), intercropping with other crops (8%) and intercropped with calliandra on external (4%) and internal boundaries (4%) (Table 19).

Table 19: Niches where farmers planted fodder legumes

Niche	Calliandra Percentage	Desmodium Percentage
Internal boundary	59	4
External boundary	21	4
Inter cropped with napier grass on contours	18	38
Intercropped with napier grass on fodder banks	-	46
Intercropped with desmodium/ calliandra	4	8
Intercropped with maize	7	8
Intercropped with bananas	7	-
Intercropped with maize/bananas	4	-
Intercropped with maize beans	2	-
Intercropped with avocadoes	2	-
Pure stand fodder bank	2	4

Percentages do not sum to 100 percent because some farmers have planted in more than one niche.

Pruning tools used were variable (Table 20) but the use of shears was the most common tool reported by 46% of calliandra farmers. Thirty nine percent of the farmers used machete, while 16% used their hands to break the branches. According to Franzel *et al.*, (2002), the use of shears is recommended as they made a cleaner cut thus promoting re-growth and preventing disease and damage to the tree. Alternatively, Wambugu, (2002) suggested the use of a sharp machete to harvest the leaves but care should be taken to avoid splitting the stem or wounding the tree. All farmers who had planted desmodium used a machete to harvest it.

Table 20: Common pruning tools used

Pruning tool	Calliandra Percentage	Desmodium Percentage
Machete	39	100
Use of hand	16	-
Shears	46	-

Percentages for calliandra do not sum up to 100 percent because some farmers used more than one pruning technique.

The mean pruning height for calliandra was 3.12 feet (mean SD=0.82) with fifty-five percent of the farmers pruning at this height, which is within the range reported by Franzel *et al.*, (2002), which is also the recommended height, (Wambugu, 2002). The mean harvesting frequencies for calliandra and desmodium were 4.57 times a year (mean SD=1.33) and 4.50 times a year (mean SD=1.74) respectively. Sixty eight percent of the farmers pruned their trees at the rate of two to five times a year, with 38% pruning at the rate of four times a year. Twenty nine percent and four percent of the farmers pruned at the rate of 6 and 8 times respectively. As for desmodium, 54% of the farmers harvested their fodder at the rate of between 2 to 4 times per year. According to Mwangi, (2001), this is the minimum number of times desmodium can be harvested per year. Twenty five percent of the farmers harvested it at the rate of six times, 12.5% harvested 5 times and 8% harvested at 8 times a year. Therefore, 46% of them harvest their legume above the minimum harvesting frequency.

The cutting interval varied from season to season. The average cutting interval during the dry season was 2.70 months for both calliandra and desmodium. During wet season, the cutting interval averaged 1.3 months (mean SD= 0.45) and 1.5 (mean SD= 0.56) for calliandra and desmodium respectively. The cutting interval is short during the rainy season due to the fast regrowth, but during the dry season, regrowth is slower.

4.3.3.Feeding management

Farmer fed fodder legumes to a wide range of types of animals. The majority (88%) of the farmers fed calliandra to dairy cows, 23% fed it to heifers, 18% to mature male and 21% to calves. Similar percentage fed desmodium to cows, 13% fed it to heifers, 25% to mature males and 21% to calves (Table 21).

Table 21: Types of cattle fed on fodder legumes.

Type of animal	Calliandra Percentage	Desmodium Percentage
Dairy cows	88	88
Heifers	23	13
Mature males	18	25
Calves	21	21

Percentages do not sum to 100 percent because more than one animal is fed on legumes.

Farmers also fed fodder legumes in addition to cattle to other types of livestock. These include goats, sheep, poultry and rabbits (Table 22).

Table 22: Types of other livestock fed on fodder legumes.

Type of animal	Calliandra Percentage	Desmodium Percentage
Goats	43	63
Sheep	9	13
Poultry	7	-
Rabbits	11	4

Fifty two percent of calliandra farmers fed the fodder to their cows throughout the year while only 21% used desmodium throughout the year. Of those not feeding throughout the year, almost half fed calliandra during the first three months of year, i.e. January (48%), February (44%) and March (52%), which are usually the driest period of the year. Similarly desmodium was only fed by 42%, 26% and 42% during the first three months of the year in that order

Highest proportion of the farmers fed fodder during normal feeding, which is any other time, with 67% and 57% for desmodium and calliandra respectively. Only 29% and 13% percent fed it during milking i.e. calliandra and desmodium. According to Franzel *et al.*, (2002) fodder legumes like dairy meal are fed during milking to calm the cow. Almost all farmers (89% for calliandra and 92% for desmodium) chopped fodder before feeding, as recommended. The common tools used include, machete, chaff cutter and improvised chaff cutter (Table 23). Chopping of fodder reduces wastages.

Table 23: Tools used for chopping fodder legumes.

Type of tool	Calliandra Percentage	Desmodium Percentage
Machete	66	63
Chaff cutter	18	29
Improvised chaff cutter	5	-
Total	89	92

Most farmers feed their animals with either fresh or wilted fodder. Eighty four percent of calliandra and 75% of desmodium farmers fed it fresh. Only 11% and 13% of calliandra and desmodium farmers fed it when they are wilted. Calliandra was fed as a conserved feed (i.e. dried and preserved) by only 9% of the farmers. Therefore using the fodder when fresh was most preferred by farmers.

The average amount of fresh calliandra per cow per day was 4.47 kilograms (mean SD =2.82) (N=49), while it was 4.05 kilograms (mean SD=3.10) (N = 17) for pure desmodium and 55 kilograms (mean SD=20.81) (N=4 for desmodium – napier grass mixture. The amount was determined during interview by weighing the amount.

4.4 Benefits and constraints of fodder legumes

4.4.1 Benefits of fodder legumes

Benefits of fodder legumes could be divided into two categories. The first group consisted of benefits, which could be quantified, which included increase in milk yield reported by 84% of calliandra and 95% of desmodium farmers respectively. The average milk increases were 1.08 (mean SD = 0.46) and 0.82 (mean SD =0.34) Kilograms per cow per day for calliandra and desmodium farmers respectively. Sixty six percent of calliandra farmers were obtaining an increase of between 0.50 to 1 kg of milk per cow per day as a result of feeding their cows with the fodder, while 75% of desmodium farmers were realising an increase of between 0.25 to 0.75 kg of milk per cow per day. According to Paterson *et al.*, (1998), the impact/ increase in milk varies indicating the presence of conditioning factors on the impact such as quantity and quality of basal diet. The second group consisted of benefits which could not be quantified and these were fertility improvement, less soil erosion, saved animal health care costs, creamy milk, fence and nectar obtained from calliandra flowers.

Most farmers (91%) claimed that they derived benefits from calliandra in addition to increases in milk production. Five respondents, (9%) had not received any additional benefits from their trees. Seventy five percent of desmodium farmers also reported that they obtained extra benefits from desmodium in addition to increase in milk.

Table 24 shows the benefits, which were mentioned by farmers concerning calliandra and desmodium. Provision of fuel wood, fertility improvement, and improvement in animal health were the main additional benefits, which were mentioned by 50%, 48% and 38% of calliandra farmers respectively. Similarly 33% and 38% of desmodium farmers, mentioned fertility improvement and erosion control respectively. Weed suppression was cited by 17% of desmodium farmers. By integrating desmodium into napier grass, weeding is minimized, as the legume will cover the ground. Only two farmers noted an improvement in animal health as a result of using desmodium. According to Van der Veen, (1993) feeding fodder to a cow, the animal will be in a better condition as the leaves are of high quality, better health of the animal could also result in higher prices to farmers when sold (Place, 1998). The better health of the animal would also lead to reduced expenditure for veterinary care.

Though few farmers sold fodder leaves (3 calliandra and one desmodium farmers respectively), their markets were not developed. The leaves were sold per cutting or exchanged for other household commodities like milk and maize flour.

Table 24: Additional benefits of fodder legumes

Type of benefit	Calliandra Percentage	Desmodium Percentage
Fertility improvement	48	33
Firewood	50	-
Soil erosion control	18	38
Improvement in animal health	38	8
Creamy milk	18	4
Pole /stakes	9	-
Revenue from seedlings	13	-
Revenue from fodder	5	4
Fence	18	-
Nectar	2	-
Weed control	-	17

Percentages do not sum to 100 percent because some farmers gave more than one benefit.

Most farmers cited an increase in milk as a result of feeding calliandra to their cows. Eighty four percent of calliandra farmers observed an increase in milk production, 8% have not noticed any effect, while the same percentage did not know. Almost all (95%) of desmodium farmers noted an increase in milk as a result of feeding desmodium to their cows.

Farmers varied considerably in the way they used monies from the sale of milk (Table 25). Sixty eight percent of the farmers reported the use of money for the purchase of every day commodities (e.g. sugar, salt and detergents) with 37% of them ranking it as the most important use of the money. Thirty seven percent of the farmers reported the use of money to purchase livestock feeds with 25% ranking it as important. Between 10% and 24% used the money for payment of school fees, payment of hired labour and health care.

Table 25: Uses of money from milk sales

Use of money	Rank 1	Rank 2	Rank 3	Rank 4	% reporting
Everyday commodities	37	18	13	-	68
Livestock feeds	25	10	2	-	37
School fees	5	12	7	-	24
Paying labourer	3	8	5	-	16
Health care	-	5	3	2	10
Constructions	-	-	2	-	2

Farmers also noted that fodder legumes had some advantages when compared to the dairy meal. Fifty seven percent of calliandra farmers reported it as readily available on the farm, 51% claimed it to be cheap, as money was not needed to obtain it. The desmodium farmers reported its advantage as readily available (63%) and 38% as cheap.

Only few farmers found fodder legumes to have negative effects. The only negative effects of calliandra cited were bloat (reported by 9 farmers), which was due to excessive feeding of the animal with fodder leaves and its effect of the fodder on adjacent crops was reported by 3 farmers. Only two farmers reported the negative effect of desmodium to be its nature being weedy and spreading to other areas if not checked.

4.4.2 Constraints to fodder legume expansion

Most farmers, 77% for calliandra and 63% for desmodium claimed that they faced some constraints while trying to expand fodder on their farms. Lack of planting material-seeds /seedlings was reported by (27%) of calliandra farmers while it was not a problem to

desmodium farmers (Table 26). This is because the legume is mainly established through stem cuttings (vines). Also farmers could easily relate to the planting of stem cuttings, as this is similar to planting sweet potato vines, which they do all the time. Twenty five percent of calliandra farmers and 21% of desmodium farmers cited shortage of land. Other constraints cited were shortage of labour, reported by 20% and 21% of the farmers for both calliandra and desmodium respectively.

Table26: Constraints to fodder legume expansion.

Constraint	Calliandra Percentage	Desmodium Percentage
Lack of planting material	27	-
Lack of labour	20	21
Shortage of land	25	21
Lack of capital	7	4
Drought	7	17
None	23	37

Percentages do not sum to 100 because some farmers mentioned more than one constraint.

4.5. Economic analysis of fodder legumes

Partial budgets were developed for the fodder legumes when used as supplement in milk production. As this regarded an economic analysis from farmers' point of view, we incorporated costs and benefits associated with fodder legumes that farmers faced. According to Upton, (1979) partial budgets are appropriate for those practices that have less or limited impacts on the costs and returns of an enterprise. Farm costs which were unaffected by the changes were excluded from calculations.

To determine the net benefits of fodder legumes, opportunity costs of land, labour and capital were first estimated.

4.5.1 Opportunity cost of land, labour and capital

Opportunity cost of land

The opportunity cost of land was based on the niches where fodder legumes were planted. Since the common niches where calliandra were planted; boundaries (external and internal) e.g. on the paths and roads, which were not utilized by any crop the opportunity cost was then

assumed to be zero. This is especially so when calliandra replaces or is added to an existing hedge and is pruned frequently. Similarly the common and recommended niche for desmodium was intercropping it with napier grass on contours or on fodder banks; opportunity cost was taken as zero too.

Opportunity cost of labour

The cost of hired labour was used to determine the opportunity cost of labour. Labour was needed for planting, cutting and feeding. Because of the niches where the legumes were planted, weeding costs were excluded, as the farmers did not devote time to weed the legume as they were weeded when weeding the neighbouring crops in case of calliandra or when weeding napier grass in case of desmodium. In the research area the wage rates for casual labour were Ksh 70 per day. A working day of farm labourer consists of 6 hours, implying that an hourly rate is Ksh 11.70. Therefore the cost of labour was taken as the opportunity cost for labour.

Opportunity cost of capital: Discount rate

Since agroforestry systems involving fodder legumes are long term in nature, and in order to compare future net benefits with present day benefits, it was necessary to revalue future costs and benefits using a discount rate. By comparing the discounted Net Present Value (NPV), one is able to forecast the likelihood of proposed system being adopted (Hoekstra, 1985). In most analysis conducted from private economic point of view, usually referred to as financial analysis, analysts assumed that additional inputs required to bring about a change in the farming system could be financed by commercial credit. However, in many farm situations, the farmer would not wish or be able to borrow funds but would either have to use his own capital (equity) or forego a proportion of present production so as to be able to reap benefits later. According to Hoekstra, (1985) on most small farms, little equity capital is used as many activities attract mainly operational inputs such as family labour.

Therefore in this study, since few costs were paid in cash rather in labour, opportunity cost of capital was not considered. Also since little information is available to make a good estimation of the opportunity costs of capital at the farm level, a commonly applied discount rate of 20% was used.

4.5.2 Costs of fodder legumes

The cost of fodder legumes consisted of: costs of seedlings, planting labour, and labour for cutting and feeding the cows.

Costs of seedlings

The principle method for establishment of calliandra was by seedlings, which could be by use of Swaziland type of nursery, where bare rooted seedlings were produced or by use of polythene tubes (potted seedlings). Thus the costs of establishment varied with the method adopted by the farmer.

Of the selected farmers who had calliandra nurseries, 7 used Swaziland type of nursery, 2 used polythene tubes while one farmer used wildings transplanted into tubes to establish the seedlings (Table 27). Therefore seven farmers used bare rooted seedlings while three established their seedlings using polythene tubes (potted).

Table 27: Qualitative descriptions of fodder nurseries.

Description of the item		Frequency
Nature of seedlings	- Bare rooted	7
	- Potted	3
Season of planting	-Wet season	8
	-Dry season	2
Planting material type	-Seeds	9
	-Wildings	1
Seedlings per tube	1 seedling	2
	3 seedlings	1
Seedlings per gram of seeds		
	1-9 seedlings	4
	10-19 seedlings	1
	20-29 seedlings	1
	>30 seedlings	2

Depending on the individual farmer, establishment costs might or might not include the following operations:

(a). Nursery establishment costs: This involved activities such as ground levelling, carrying soil to the site, filling polythene tubes, manuring, sowing and shelter construction.

(b). Nursery maintenance costs involved activities such as watering and weeding.

(c). Input costs; which included costs of seeds, polythene tubes, fertilizer and manures. Other

costs were land and labour.

Total establishment costs were Ksh1, 027 for bare rooted seedlings and Ksh 1,004 (s.d = 751.25) for potted seedlings respectively (Table 28). The number of bare rooted seedlings established was high 2,692 compared with 695 as for the case of potted plants. The average cost per bare-root seedling was Ksh 0.38 and Ksh 1.44 for potted seedlings. The difference in cost per seedling between bare-rooted and potted seedlings was significant at p = 0.10 (t-test).

Table 28: Comparison of establishment costs of seedlings using different types of nurseries (Ksh).

	Bare rooted seedlings		Potted seedling	
Activity/ inputs	Av. cost (Ksh)	No. incurring the cost	Av. cost (Ksh)	No. incurring the cost
Nursery estab.	40.47 (26.17)	7	160.95 (126.84)	3
Nursery maint.	543.76 (404.24)	7	684.43 (712.18)	3
Fertilizer cost	3.27 (5.16)	3	4.50 (3.89)	2
Manure cost	83.57 (60.60)	6	26.66 (30.55)	2
Cost of seeds	356.81 (303.45)	7	50	2
Cost of wildings	0	0	15.50	1
Cost of tubes	0	0	62.50 (56.29)	3
Totals	1027.88	7	1,004.64(751.25)	3
No. of seedlings	2,692.85 (3,314.22)	7	695.00 (715.20)	3
Cost per seedling	0.38	7	1.44	3

Standard deviations are in parenthesis

Table 28 also showed that establishing calliandra seedlings did not need a high investment of capital, most activities involved labour except fertiliser, which was used by only 3 farmers. If family labour and manure were available and could be used and seeds collected from own farm, capital would only be needed to buy fertiliser. In general, a farmer could decrease costs by raising own seedlings by using bare rooted seedlings. However, the advantages of tubes (potted seedlings), was that the survival rate of seedlings was greatly improved especially if there was scarcity of water.

The analysis further showed that the mean number of seedlings from one gram of seeds used was 18.98 (mean SD = 16.98), with 4 farmers getting less than 10 seedlings. This was higher than 10 seedlings per gram of seeds reported by Wambugu, (2002). The differences may be due to the fact that farmers were provided with seeds in the previous study, while in the present

study, farmers collected seeds from own farms. Most farmers, 8 established their seedlings during wet season (Table 27).

For desmodium, propagation was easy because cuttings could be transplanted. Farmers obtained planting material (cuttings) from neighbours or friends at no cost. Since there was no well-defined market for the cuttings, the amount a farmer was willing to pay was taken as the price of the cuttings. The price varied across farmers with Ksh 281 (mean SD = 245.06; median = 200) being the average price that the farmers were willing to pay for an average of 2.3 handfuls (mean SD = 2.75) of desmodium cuttings. Therefore, the average price per handful of cuttings was Ksh 122. Most (60 %) farmers were willing to buy desmodium cuttings at the range of Ksh 101 to Ksh 200 per handful (Table 29). According to Mwangi and Wambugu, (2002) since desmodium seeds are small, sowing requires extra care and extra labour is needed especially during planting season when the demand for labour for planting food crops was high. Also the tiny seedlings that emerge make weeding difficult. Therefore the most common method was by use of vines/ cuttings.

Table 29: Amount farmers were willing to pay per handful of desmodium cuttings (Ksh)

Expenditure range (Ksh)	Percentage
50 – 100	35
101 – 200	60
201 –300	5
Total	100

Planting labour

The total labour costs varied with the number of seedlings a farmer had planted on his or her farm.

According to Franzel *et al.*, (2002), labour requirements for planting calliandra is 20 seedlings per hour. This included transport to the field. Given that the farmers were paying Ksh 11.70 per hour, (section 4.5.1), therefore they will be using Ksh 11.70 to plant 20 seedlings. Labour requirements for planting desmodium were based on the area of legume that a farmer had planted. On average, farmers planted 882 square metres (s.d = 960.80) of napier-fodder mixture using 2.6 hours (s.d = 2.87). This implied that they planted 340 square metres per hour. This included digging the holes and planting. The farmers were paying Ksh 70 per man-day and therefore a farmer would use Ksh 0.04 to plant a square metre of napier- grass legume mixture.

Weeding labour

Most of the land management practices like weeding done on neighbouring crops benefited legumes as well. Because of the niches where fodder legumes were planted, it seemed that no extra weeding was needed on them (fodder legumes) on top of normal weeding of napier grass and or adjacent crops in the case of desmodium and calliandra respectively. Their weeding therefore did not take extra time. After every cutting, the napier grass is weeded, which is done simultaneously with fodder. Therefore no extra costs for labour for weeding was calculated for the legumes.

Harvesting and feeding labour

On average, the time spent feeding a cow per day for the selected farmers was 18 minutes, (s.d = 8.4; median =15) for an average of 4.4 kgs of calliandra and 26 minutes (s.d = 8.1; median = 30) for an average of 4.5 kilograms of desmodium. Most (70%) farmers were spending between 10 to 19 minutes per day per cow cutting and feeding calliandra, while for desmodium most (65%) were spending between 30 to 39 minutes (Table 30).

Table 30: Time spent cutting and feeding desmodium and calliandra per cow per day

Time range (minutes)	Desmodium Percentages	Calliandra Percentages
10 –19 minutes	30	70
20 – 29 minutes	0	0
30 – 39 minutes	65	30
40 – 49 minutes	5	0
Total	100	100

Most (65%) farmers were giving between 1 to 4 kgs of desmodium to a cow per day, while 80% of calliandra farmers were giving between 3 to 6 kgs of the fodder to a cow per day (Table 31). The feeding consisted of cutting the fodder from the field and carrying to the cattle enclosures (pen), and chopping before giving it to the animal. After the second year, a total of 109 hours and 158 hours were needed per cow per year for calliandra and desmodium respectively to get all the extra labour on fodder legumes done.

Table 31: Amount of fresh fodder fed to a cow per day (Kgs)

Fodder amount range (kg)	Desmodium Percentages	Calliandra Percentages
1 –2 kg	25	0
3 – 4 kg	40	50
5 – 6 kg	10	30
7 – 8 kg	5	0
9 –10 kg	20	5
11-12 kg	0	15
Total	100	100

4.5.3 The partial budget analysis: Calliandra as a supplement

Partial budgets were used to determine the net benefits of calliandra when used as a supplement. Average values for costs and returns across sample farmers were used to compute the net benefits. Coefficients and prices used in the analysis are in Table 32 while results are presented in Table 34. It was assumed that calliandra and dairy meal are fed 365 days per year as is recommended, whether the cow is in lactation or not. A lactation period was assumed to be 300 days and the period of analysis was taken to be 10 years. Infact, it has been noted that the productive life of the tree can be longer as farmers who have had this legume for the last 10-12 years have not noted any reduction in productivity.

Table 32: Coefficients and prices used when calliandra is used as a supplement

Item	Values	Data sources
Coefficients		
Lactation period	300 days	Assumption
Days fed calliandra	365 days	Assumption
Period of analysis	10 years	Assumption
Dairy meal per cow per day	1.3 kg	Farmers
Days fed dairy meal	365 days	Assumption
Fresh calliandra quantity fed /cow/day	4.4 kg	Farmers
Extra milk /cow/day	1.09 kg	Farmers
Calliandra planting labour	20 plants per hour	Franzel *et al.*, 2002
Calliandra cutting and feeding labour	18 minutes per day	Farmers
Discount rate	20%	Assumption
Average seedling survival rate	76.5%	Franzel *et al.*, 2002 and Wambugu 2001
Prices (Ksh)		
Seedlings cost (bare rooted)	0.38 per seedling	Farmers
Milk price (farm gate)	14.35 per kg	Farmers
Labour cost	70 per day	Farmers
Annualised value of fixed cost for seedling establishment for 358 shrubs	91	Capital recovery formula* Spencer *et al.*, 1979
1 US$ = 76 Kenya shillings Average exchange rate, 2003		GoK, 2004

*$K = (rv) / (1-(1+ r)^{-n})$, Where K is the annual service user cost, v is the original cost of fixed capital asset, r is the discount rate, and n is the expected life of the asset.

The assumptions and data in Table 32 were used to compute the final results. According to our data, the average farmer had initially planted 468 calliandra trees, 358 survived and had one dairy cow and that calliandra trees were established using bare-rooted seedlings. Average survival rate of 76.5% was used to estimate the initial number of trees that were planted by the farmer. Survival rate of seedlings was obtained by taking the averages from Franzel *et al.*, (2002) and Wambugu (2001), which were 97% and 60% respectively. The two rates were from good rain and other from drought year. By supplementing 4.4 kilograms of fresh calliandra to cow's normal diet (which included dairy meal) resulted in an increase of 1.09 (mean SD =0.38; median =1.0) kilograms of milk per cow per day. Assuming that the cows were given the recommended 6 Kgs of fodder as recommended, (Roothaert *et al., 2001*), the increase in milk

would have 1.62 Kg per 6 kg of fresh calliandra. Half of the sampled farmers were realising an increase of between 0.78 –1.32 kg of milk per 6 kg of fresh calliandra (Table33). The increase per cow per day was higher than 0.6 kg of milk per cow per day reported by Roothaert *et al.*, (2001) where farmers were supplementing 6 kilograms of fresh fodder to cow's diet. According to Paterson *et al.*, (1998), variability in response depends on such factors as the health of the animal and the quantity and quality of the basal feed

Table 33: Milk increase per 6 kg of fresh calliandra according to farmers

Milk increase range (kg)	Percentage
0.78 – 1.02 kg	35
1.08 – 1.32 kg	15
1.38 – 1.62 kg	25
1.62 – 3.0 kg	25
Total	100

Shrub establishment costs i.e. cost of seedlings and planting were Ksh 451 (Table 34). By supplementing calliandra throughout the lactation period, milk production increased by 329 kilograms per cow per year. The resulting net benefits were Ksh 3,410.52 (mean SD =2331; median =3,195) per cow per year beginning the second year. Most farmers (55%) obtained net benefits of between Ksh 2,001 to 6,000 per cow per year (Table 35).

In the calculation, it was assumed that the effect of legume on milk yield remained the same throughout the lactation period as the average increase across the sampled farmers were used taking care of different stages of lactation. The Net Present Value (NPV) assuming a 20% discount rate was Ksh 7,920 per cow per year. By treating establishment costs as depreciation spread over the ten- year period, the annualised net benefits were Ksh 3,319 per cow per year. In determining annualised benefits, capital recovery formula was used. The procedure allowed both the depreciation on the capital and the opportunity cost of the capital to be costed out (Spencer *et al.*, 1979).

Table 34: Partial budget: Extra costs and benefits of using calliandra as a supplement for increasing milk production (Ksh/cow/year, 2003).

Year	Item	Extra cost Ksh		Extra benefits Ksh	Net benefits Ksh
1	Fodder seedlings	177			
	Planting labour	274			
	Subtotals	451		0	- 451
2	Cutting and feeding costs	1,323	Extra milk (329 kg)	4734	3,410.52

3 –10 same as year 2

Net present value at 20% discount rate = Ksh 7,920

Annualised net benefits treating establishment costs as depreciation =Ksh 3,319

Note: The farm had initially planted 468 calliandra trees of which 358 survived and one dairy cow. Other assumptions and coefficients are shown in Table 32.

Table 35: Distribution of farmers as per net benefits when calliandra is used as a supplement

Net benefits range (Ksh)	Percentage
Less than zero	
-335.25	5
-35.25	5
1 - 2000	20
2001 – 4000	30
4001 – 6000	25
6001 – 8000	10
8001 – 8145	5
Total	100

Assuming the farmer had 500 calliandra trees, the net benefits per cow per year would be Ksh 4,763, which is equivalent to US$ 62 at the current exchange rate[4]. This is less than that reported by Franzel, (2004) where the net benefits were US$ 79 per cow per year. The lower result could be due to the following reasons, one, milk prices has declined from Ksh 17 to Ksh 14 in the present study and secondly, labour cost has increased from Ksh 11.40 per hour to Ksh 11.70 in the present study.

A further analysis of the net benefits under different scenarios when calliandra is used as a supplement revealed the following;

[4] 1US$ =76 Ksh (2003)

(a) Gender

The average net benefits were Ksh 2,961 (s.d = 2,356) (N=12) and Ksh 4,084 (s.d = 2,273) (N=8) for male and female managed farms respectively (Table 36). Due to small sample size and high variability, the differences (t- test) were not significant at p = 0.3. Small sample sizes restrict significance between variables. The higher net benefits realised by the female headed households may be attributed to the fact that women in most cases are the ones who collect organic feeds for animals. Now days however the role of women as decision makers is becoming more important. The standard deviation of the net benefits was large due to high range (variability), (Table 35).

Table 36: Net benefits when calliandra is used as supplement as per gender of the farm manager

Gender of farm manager	Mean net benefits (Ksh)	N	Std deviation (Ksh)
Male	2,961	12	2,356
Female	4,084	8	2,273
Weighted mean	3,410.52	20	2,331.78

(b) Cattle management level

Farmers were categorized into different cattle management levels based on indices developed by combining different cattle attributes (see management levels of cattle enterprise). The selected farmers fitted only into two categories, the high and medium levels. None was on the lower level. By using calliandra as a supplement, the net benefits obtained were Ksh 3,440 (s.d = 2,307) and Ksh 3,289 (s.d = 2,791) for farmers on higher cattle management and medium management levels respectively (Table 37). The differences (t-test) were not significant at p = 0.91.

Table 37: Net benefits when calliandra is used as supplement under different cattle management levels.

Cattle management level	Mean net benefits (Ksh)	N	Std.deviation (Ksh)
High	3,440	16	2,307
Medium	3,289	4	2,791
Weighted mean	3,410.52	20	2,331.78

(a) Gender

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Medium	3,289	4	2,791
Weighted mean	3,410.52	20	2,331.78

(c) Market access

Based on the distance between the point of observation (homestead) and some market destination (main road- where public service vehicles pass), market accessibility was categorised into (1) more than two or (2) zero to two kilometres. The net benefits were Ksh 3,675 (s.d = 2,178) (N = 5) and Ksh 3,322 (s.d = 2,447) (N = 15) for farmers who were more than 2 Km and less than 2 Km respectively (Table 39).

The maximum transport cost were realised when the farmer were 5 to 6 kilometres away from the main road, where the cost of transporting a bag of dairy meal was Ksh 50 per 70 kg bag, while it was Ksh 17 for a farmer who is closer to the road (Table 38). Milk prices were within the range of Ksh 13.90 to Ksh 15 per kg and oddly enough, did not vary with distance.

Table 38: Transportation costs of dairy meal and milk prices under different access to markets

Distance (kilometres)	Tpt[5] cost/bag (Ksh)	No. of farmers	Milk price (Ksh)	No. of farmers
0 –1 kilometre	17	5	13.90	6
1 –2 kilometres	20	1	14.50	9
2 –3 kilometres	15	2	15	4
3 –4 kilometres	0	0	0	0
4 –5 kilometres	0	0	0	0
5 –6 kilometres	50	1	14	1
Average	21	-	14.35	-
Total	-	9	-	20

Table 39: Net benefits when calliandra is used as supplement under different access to markets

Distance (km)	Mean net benefits (Ksh)	N	Std deviation (Ksh)
0 - 2 Kilometres	3,322	15	2,447
More than 2 kilometres	3,675	5	2,178
Weighted mean	3,440.52	20	2,331.78

From Table 39, higher net benefits were realized when the farmers were more than two kilometres to the main road. The net benefits when calliandra was used as a supplement was positively correlated with the distance from the homestead to the main road where public vehicles pass (Pearson correlation coefficient = 0.77, P = 0.07). This might be attributed to milk prices, which increased as one moves further from the main road (Table 38), though the quality of the road was almost the same. Most farmers (19 of 20) were within the distance of up to 3 kilometres.

[5] Tpt means transport

4.5.3.1 Calliandra as a substitute; assuming farmers used calliandra instead of dairy meal

Since the effects of calliandra and dairy meal on milk production is additive, the two feeds are therefore nutritionally interchangeable (Paterson *et al.*, 1996). By assuming that farmers were using calliandra instead of dairy meal, then they would be saving the cost and the transportation cost of dairy meal. Coefficients and prices used in the analysis are in Table 40 while results are presented in Table 41.

Table 40: Coefficients and prices used when calliandra is used as a substitute of dairy meal in milk production.

Item	Values	Data sources
Coefficients		
Lactation period	300 days	Assumption
Days fed calliandra	365 days	Assumption
Dairy meal per cow per day	1.45 kg	Assumption
Days fed dairy meal	365 days	Assumption
Period of analysis	10 years	Assumption
Fresh calliandra quantity fed /cow/day	4.4 kg	Farmers
Calliandra planting labour	20 plants per hour	Franzel *et al.*, 2002
Calliandra cutting and feeding labour	20 minutes per day	Farmers
Discount rate	20%	Assumption
Average seedling survival rate	76.5%	Franzel *et al.*, 2002 and Wambugu 2001
Prices (Ksh)		
Dairy meal price	900 per 70 kg bag	Farmers
Transport of dairy meal	20 per 70 kg bag	Farmers
Seedlings cost-bare rooted	0.38 per seedling	Farmers
Labour cost	70 per day	Farmers
Annualised value for fixed cost for seedling establishment for 358 shrubs	100	Capital recovery formula* Spencer *et al.*, 1979

*As previously defined

The above assumptions above were used to compute the final results.

The economic benefit of using calliandra, as a substitute assuming farmers were using it instead of dairy meal was the cost of saved dairy meal. Since 3 kg of fresh calliandra (1 kg dry) has about the same positive effect on milk production as 1kg of dairy meal (ICRAF, 1996) and given that the two feeds are nutritionally interchangeable, the amount of dairy meal which could have been used was 1.45 kg per cow per day. By using 4.4 kg of fresh calliandra, the farmer would save 1.45 kg of dairy meal per cow per day. Therefore by using calliandra, the

farmer saves the money he would have spent buying and transporting 529 kg of dairy meal per year. On average, a farmer would save Ksh 6,974 per cow per year by using calliandra instead of dairy meal. The resultant net benefits per cow per year by using calliandra, as a substitute for dairy meal was Ksh 5,651 with the NPV being Ksh 22,209, and the annualised benefits being Ksh 5,551 (Table 40).

Table 41: Partial budget: Extra costs and benefits of using calliandra as a substitute assuming farmers used it instead of dairy meal in milk production (Ksh/cow/year, 2003).

Year	Item	Extra cost Ksh	Extra benefits Ksh		Net benefits Ksh
1	Shrub seedlings	177			
	Planting labour	274			
	Subtotals	451		0	- 451
2	Cutting and feeding costs	1,323	Saved dairy meal cost	6,774	
			Saved dairy meal transport	200	
			Sub total	6,974	5,651

3 –10 same as year 2
Net present value at 20% discount rate = Ksh 22,209
Annualised net benefits treating establishment costs as depreciation =Ksh 5,551
Note: The farm had 468 calliandra trees of which 358 survived and one dairy cow.

4.5.4 The partial budget analysis: Desmodium as a supplement

Partial budgets were also developed in evaluating the net benefits of desmodium when used as supplement to increase milk production. Coefficients and prices used in the analysis are in Table 42 while results are presented in Table 44. Like in the case of calliandra, it was assumed that desmodium and dairy meal are fed 365 days per year as is recommended, whether the cow is in lactation or not. A lactation period was assumed to be 300 days and the period of analysis was taken to be 10 years.

Table 42: Coefficients and prices used when desmodium is used as a supplement in milk production.

Item	Values	Data sources
Coefficients		
Lactation period	300 days	Assumptions
Days fed desmodium	365 days	Assumption
Dairy meal per cow per day	0.88 kg	Farmers
Fresh desmodium quantity fed /cow/day	4.5 kg	Farmers
Extra milk /cow/day	0.77 kg	Farmers
Desmodium planting labour	340 m^2 per hour	Farmers
Desmodium cutting and feeding labour	24 minutes per day	Farmers
Discount rate	20%	Assumption
Prices (Ksh)		
Average cost of vines (cuttings)/ handful	122	Farmers
Milk price	15.40 per kg	Farmers
Annualised value for fixed cost for Fodder establishment (882 square metres of desmodium).	46	Capital recovery formula* Spencer *et al., (1979)*

*As previously defined.

The above assumptions were used to compute the final results. The establishment costs i.e. cost of stem cuttings (vines), which were the main method used to establish desmodium was Ksh 281 for an average of 2.3 handfuls. Supplementing 4.5 kilograms of fresh desmodium throughout the lactation period increased milk production by 232 kilograms per cow per year (an increase of 0.77 (s.d =0.34; median =0.75) kilograms of milk per cow per day. This was equivalent to an increase of 0.17 kg of milk per kg of fresh desmodium. Thirty five percent of the farmers were realising an increase of between 0.13 –0.17 kg of milk per kg of fresh desmodium (Table 43).

Table 43: Milk increase per kg of fresh desmodium according to farmers

Milk increase range (kg)	Percentage
0.05– 0.15	35
0.16 – 0.22	15
0.23 – 0.27	25
0.28 - 0.75	25
Total	100

The resulting average net benefits were Ksh 1,690 (s.d =1,656; median = 1,568) per cow per year beginning the second year (Table 44). Most farmers (65%) obtained net benefits of

between Ksh 0 to 4,000 per cow per year (Table 45)

In the calculation, as in the case of calliandra, it was assumed that the effect of legume on milk yield remained the same throughout the lactation period as the average increases across the sampled farmers was used which took care of different stages of lactation. The NPV was Ksh 6,498 and annualised net benefits were Ksh 1,583.80per cow per year.

Table 44: The partial budget: Extra costs and benefits of using desmodium as a supplement for increasing milk production (Ksh/cow/year, 2003).

Year	Item	Extra cost Ksh	Extra benefits Ksh	Net benefits Ksh
1	Cost of vines	281		
	Planting labour	30		
	Subtotals	311	0	-311
2	Cutting and feeding costs	1,900	Extra milk (232 kg) 3,590.60	1,690.60

3 –10 same as year 2
Net present value at 20% discount rate = Ksh 6,498
Annualised net benefits treating establishment costs as depreciation =Ksh 1,583.80
Average area of desmodium was 882 square metres.

Table 45: Distribution of desmodium farmers as per net benefits

Net benefits range (Ksh)	Percentage
Less than zero	
(-785.25)	10
-335	5
-35.25	5
0 – 2,000	45
2,001 – 4,000	20
4,001 – 6,000	15
Total	100

The net benefits of using desmodium as a supplement under different scenarios revealed the following:

(a) Gender

The average net benefits were Ksh 1,718 (s.d =1,689) and Ksh 1,637 (s.d = 1,723) for male and female managed farms respectively (Table 46). The standard deviation of the net benefits was large due to high variability. The differences (t- test) was not significant at p = 0.90. This could be attributed to the fact that there were little differences in the average net benefits between the two groups, which was only Ksh 81.

Table 46: Net benefits when desmodium is used as a supplement as per gender of the farm manager

Gender of farm manager	Mean net benefits (Ksh)	N	Std deviation (Ksh)
Male	1,718	13	1,689
Female	1,637	7	1,723
Weighted mean	1,690	20	1,656

b) Cattle management level

Farmers were categorized into different management levels. The selected farmers who were using desmodium as a supplement fitted into two categories, the high and medium levels. By using desmodium as a supplement, the net benefits obtained were Ksh 1,368 (s.d = 1,672) and Ksh 2,012 (s.d =1,661) for farmers on higher cattle management and medium management levels respectively (Table 47). Also, the standard deviations of the net benefits were large due to high range (variability). The difference (t- test) was not significant at p = 0.40.

Table 47: Net benefits when desmodium is used as a supplement under different cattle management levels.

Cattle management level	Mean net benefits (Ksh)	N	Std deviation (Ksh)
High	1,368	10	1,672
Medium	2,012	10	1,661
Weighted mean	1,690	20	1,656

c) Market access

The net benefit realized by the farmers within the distance of up to two kilometres from the main road was Ksh 1,378 (s.d = 1,532), while the farmers who were over two kilometres from the main road realized the net benefits of Ksh 2,268 (s.d = 1,839) (Table 49). The standard deviations of the net benefits were large due to high range (variability). The difference (F- test) was significant at p = 0.26. This might be attributed to milk prices, which increased as

one moves further from the main road (Table 48), which were on average Ksh 15.30 and Ksh 15.78 per kg within the distance of up to two kilometres and more than two kilometres respectively.

The maximum transport cost were realised when the farmer were 5 to 6 kilometres away from the main road, where the cost of transporting a bag of dairy meal was Ksh 50 per 70 kg bag, while it was Ksh 17.50 for a farmer who is closer to the road (Table 48). Milk prices were within the range of Ksh 15 to Ksh 16 per kg.

Table 48: Transportation costs of dairy meal and milk prices as per distances to main road

Distance (kilometres)	Tpt cost/bag (Ksh)	No. of farmers	Milk price (Ksh)	No. of farmers
0 –1 kilometre	17.50	2	15.66	6
1 –2 kilometres	0	0	15	7
2 –3 kilometres	0	0	15.83	3
3 –4 kilometres	0	0	0	0
4 –5 kilometres	10	2	16	2
5 –6 kilometres	50	1	15.50	2
Average	16.73	-	15.47	-
Total	-	5	-	20

Table 49: Net benefits when desmodium is used as a supplement as per distances to main road

Distance in kilometres	Mean net benefits (Ksh)	N	Std deviation (Ksh)
0 - 2 kilometres	1378	13	1532
>2 kilometres	2268	7	1839
Weighted mean	1690	20	1656

4.6 Comparison of net benefits of calliandra and desmodium

In general, calliandra farmers were getting higher net benefits (Ksh 3410.52 per cow per year) compared to desmodium farmers (Ksh 1690 per cow per year). The differences in net benefits, was significant at $p = 0.01$ (t-test). This could be attributed to the following; firstly, differences in impact of fodder on milk, which averaged 0.17 kg of milk per kg of desmodium and 0.27 kgs of milk per kg of calliandra. The differences were significant at $p = 0.009$ (t-test). Also, the time taken for cutting and carrying desmodium to the cows' shed/pen was also higher (26 minutes per cow per day, for an average of 4.5 kgs of fresh desmodium) than 18 minutes for almost similar amount of calliandra (4.35 kgs), which was significant at $p = 0.003$ (t-test). This means that desmodium consumes more time (labour intensive) than calliandra in terms of cutting and carrying it to livestock, thus increasing the cost. One farmer reported that

desmodium takes more time to cut because the farmer has to bend down to the ground to collect whereas calliandra branches can be cut while standing.

Relationships between the net benefits and the scenarios was analysed using Pearson correlation coefficient. There was a positive correlation between cattle management level and the net benefits realised by desmodium farmers (Pearson correlation coefficient = 0.20, P = 0.399). This implies that higher net benefits are realised by those farmers on medium level of management, though the differences were not statistically significant. However, for calliandra farmers, net benefits were negatively correlated cattle management (Pearson correlation coefficient = -0.027, P = 0.91). The relationship between the net benefits and the sex of the farm manager was negative in the case of desmodium (Pearson correlation coefficient = -0.024, P = 0.90), implying that males headed farms were realising higher net benefits, while in the case of calliandra, the net benefits was positively correlated with gender (Pearson correlation coefficient = 0.24, P = 0.30). There was a positive correlation between the net benefits and the distance between the homestead and the main road (market access) for both types of fodder (Table 50). This might be attributed to milk prices, which increased as one moves further from the main road

Table 50: Pearson correlation coefficients of the net benefits of calliandra and desmodium

	Desmodium		Calliandra	
Scenario	Pearson coefficient	Significance (P)	Pearson coefficient	Significance (P)
Gender	-0.024	0.92	0.24	0.30
Cattle mgt	0.20	0.39	-0.027	0.91
Market access	0.26	0.26	0.67	0.77

4.7 Farmer innovations concerning fodder legumes

4.7.1 Types of farmer innovations concerning fodder legumes

Farmer innovation has led to development of diverse management practices on fodder by farmers. The practices that farmers were testing were somewhat different than those that researchers first introduced (recommended) to farmers. Innovations were evident in the method of establishment, tree management practices and how the farmers were using it (utilization). In response to an open question, 30% of calliandra farmers claimed they have made some

innovations. The innovations made concerned fodder uses while few were made on tree management. This supports assertion by Saad, (2002) that vast majority of local innovations are of adaptive research. They seek marginal improvement on standard practice by testing variation of limited set of elements that are either brought from outside or are already available in the system. Some of innovations done by farmers are explained below.

4.7.1.1 Innovations concerning niches and establishment

Some of the innovations were observed from farmers' practices, which differed considerably from what researchers or extensionists recommended. The notable innovations noted were the niches where the legumes were planted and how they were established. Apart from the common niches where farmers planted calliandra i.e. internal (homestead) boundaries, external boundaries, intercropping with other crops, intercropping with napier grass on contours and as pure stand fodder bank, another niche which was identified was the intercropping calliandra with desmodium, reported by 4% of the farmers (2 farmers). Inter cropping calliandra with desmodium appeared to be an innovation by the farmer as the other niches were reported by previous research (Franzel *et al.,* 2002). Though the common niche for desmodium is integration with napier grass either on contours or on fodder banks, other niches where farmers had planted desmodium were as pure stand (4%), intercropping with other crops (8%) and intercropped with calliandra on external and internal boundaries (both, 4%) Also farmers' practice of intercropping desmodium with calliandra on the internal and external boundaries is an innovation, which was observed.

There was an important innovation on establishment. During the rainy season, one farmer collected calliandra wildings and planted in tubes. The advantage of this innovation was that the seedlings were found to grow faster.

4.7.1.2 Innovations concerning fodder management

Pruning tools used in calliandra were shears, use of machete and breaking by hand. The use of shears and a sharp machete was recommended as they make a cleaner cut, thus promoting regrowth and prevent disease and damage to the shrub (Franzel *et al.*, 2002; Wambugu 2002). The use of hand can be termed as an innovation. All desmodium farmers used machete as they are usually harvested together with napier grass.

The mean pruning height for calliandra was 3.12 feet (mean SD=0.82) with fifty-five percent of the farmers pruning at about three feet, which is within the range reported by Franzel *et al.*, (2001), which was also the recommended height, (Wambugu, 2002). About three quarters of the farmers pruned at the height of between 1.5 feet to 3 feet high (Table 51). Farmers who pruned below 2 feet were considered to have innovated.

Table 51: Distribution of farmers according to harvesting height of calliandra

Approximate pruning height (feet)	Percentage
1.50 feet	5
2.0 feet	11
2.5 feet	2
3.0 feet	55
3.50 feet	4
4.0 feet	16
5.0 feet	7
Total	100

The mean harvesting frequencies for calliandra and desmodium were 4.57 times a year (mean SD=1.33) and 4.50 times a year (mean SD=1.74) respectively. Most farmers (67.9%) pruned their trees at the rate of two to five times a year, with 38% pruning at the rate of four times a year. Only 29% and 4% pruned at the rate of 6 and 8 times respectively, hence considered to have innovated. As for desmodium, 54.2% harvested their fodder at the rate of between 2 and 4 times a year, which is the minimum per year (Mwangi, 2001). Only 25% harvested it at the rate of six times, 12.5% harvested 5 times and 8.3% harvested at 8 times a year. Therefore 45.8% harvest their legume above the minimum harvesting frequency.

4.7.1.3 Innovations concerning fodder uses

Farmers also fed fodder legume (calliandra) in addition to cattle to other types of livestock. These included goats, sheep, poultry and rabbits. Since the legume was initially introduced as an important nitrogen rich supplement for increased milk production in dairy production, farmers have expanded the range of livestock fed on it to include the ones mentioned above, thus innovating as far as its utilisation was concerned. Highest proportion of the farmers fed fodder during normal feeding, which is any other time, with 67% and 57% for desmodium and calliandra respectively. Only 29% and 13% percent fed it during milking i.e. calliandra and

desmodium. Almost all farmers (89% for calliandra and 92% for desmodium) chopped fodder before feeding, as recommended. The common tools used included machete, chaff cutter and improvised chaff cutter (Table 52). The use of improvised chaff cutter can be termed as an innovation.

Table 52: Tools used for chopping fodder legumes.

	Calliandra		Desmodium	
Type of tool	Frequency	Percent	Frequency	Percent
Machete	37	66.1	15	62.5
Chaff cutter	10	17.9	7	29.2
Improvised chaff cutter	3	5.4	-	-
Total	50	89.3	22	91.7

Most farmers fed their animals with either fresh or wilted fodder. Most (84%) of calliandra farmers feed it fresh, while 75% of desmodium farmers fed it fresh. Eleven percent and 12.5% of calliandra and desmodium farmers fed it when they are wilted. Calliandra was fed as a conserved feed by only 9% of the farmers, that is the legume is harvested, dried, stored and used later on. This was used as a preservation method.

During the rainy season when there were excess leaves due to faster re-growth of the legume (calliandra), and in order to maintain pruning height, leaves were cut and left to decay especially those intercropped with napier grass or other crops in the farm. The effect was noted in the appearance of the napier grass or crops compared to other crops or napier grass where the practice had not been carried out. The change in appearance due to new practice implied that the legume could improve the fertility of the soil. This could be due to the high nitrogen content of the leaves and the nitrogen fixing aspect of fodder. Therefore cutting and leaving the leaves to decay in the field so as to improve the fertility of the soil can be termed as an innovation. Some farmers (3) also harvested calliandra when in excess then dried and stored to be used later especially during the dry season/during shortages. When used later, its effect on milk yield was found to be the same as when fresh. The advantage of this innovation was that it was used as a preservation method.

In addition of being used as a fodder, some farmers (3) reduced spacing (30 cm) of calliandra in order to make hedge (live). One farmer planted double rows in order to ensure that

the branches interlock thus giving a strong hedge. This type of innovation was noticed around the homestead (internal boundary) and as partitioning in the farm. The fence did not affect neighbouring crops. The innovation (reduction in spacing) had the advantage of being acting as hedge and when trimming it, the leaves can be used as fodder.

Other farmers (5) dried the leaves and mixed with bran then fed livestock. This innovation resulted in increase in milk, like when dairy meal is used. Additional benefit of the innovation was the reduction in cost as bran was used which was cheaper than dairy meal. Some (2 farmers) fed the mixture to poultry where they noted that those that are fed on it grew faster. One farmer dried the leaves and mixed with indigenous fodder e.g. 'muthatha' and 'mubembu' and used it on dairy goats where he observed an increase in milk.

Goats and rabbits were used to debark calliandra stakes before being used as firewood. The farmer mentioned that the rabbits that were given the stakes showed improved health (soft fur). Also when used as firewood, the resulting ashes could be used to control maize stalk borer. The farmer noted that it controls the pest to some extent.

4.7.1.4 Summary of innovations undertaken by farmers

Table 53 summarises the innovations made concerning calliandra as reported by farmers. Only 17 farmers claimed that they have innovated.

Table 53: Farmer innovation concerning calliandra

Innovation made	Percentage
1. Compost (calliandra cut and left to decay)	5
2. Dry calliandra and fed to dairy cows	5
3. Dry and mixed with bran and fed to dairy cows	9
4. Dry and bran fed to poultry	4
5. Live fence	5
6. Use of wildings for establishment	2
7. Dry and mixed with indigenous fodder	2
8. Feeding calliandra alone to dairy cows (no commercial feed)	4
9. Debarking of stakes by goats and rabbits	2
10. Ash from calliandra wood used to control stalk borer	2

Note: Some farmers made more than one innovations.

Because of the positive effect of the innovations, most farmers decided to continue,

depending on the circumstances for example if they had excess calliandra (Table 54). All the farmers did not report any disadvantage of the innovations

Table 54: Farmers ' perception of the innovations

Innovation made	Advantage of innovation	Decision made
1. Compost; calliandra cut excess fodder and left to decay in the farm	Fertility improvement	Continue if there is
2. Dry calliandra and fed to livestock	Conservation method	Continue if there is excess fodder
3. Dry and mixed with bran and fed to poultry	Poultry grow faster	Continue using
4. Fence- calliandra acting as hedge	Ornamental	Continue using
5. Wildings used for establishment	Saves time	To use during rains
6. Dry calliandra mixed with indigenous fodder and fed to goats	Results in increase in milk-goats	Plant more fodder, both calliandra and indigenous
7. Feeding calliandra alone to livestock i.e. without dairy meal	Cost reduction	Plant more calliandra trees
8. Debarking of stakes by goats and rabbits	Improvement in health of rabbits	Debark before using as firewood
9. Dry and mixed with bran and fed to dairy cows	Preservation measure, increases milk yields and cost reduction	Continue, reduced dairy meal use
10.Use of ash to control maize stalk borer	Cost reduction	Continue,

4.7.2 Factors influencing innovation in fodder legumes

Investigation of the factors affecting innovation was based on conceptual framework developed earlier (see conceptual framework section). In the framework, farmers' decision to innovate is influenced by the age, gender, education level, experience with the technology, wealth levels, extension, rank of dairy enterprise and management level of dairy enterprise. Descriptive statistics of all variables used in the empirical model, are presented in Tables 55 and 56.

Table 55: Continuous variables used in the logistic model

Variable	Mean	Std dev	Min.	Max.	N	Label
AGE	55.8	11.18	26	79	56	Age of the farm manager in years
EDUC	6.87	4.31	0	15	56	Education level of farmer in years
EXP (Call)		11.01	4.98	2	18 56	Fodder experience–calliandra in years
EXTN	1.91	2.60	0	12	56	Extension visits over one year
RODE	1.69	0.89	1	4	49	Rank of dairy enterprise

Table 56: Non-continuous variables used in logistic model

Variable	Group	Code	No. of farmers	Percentage
Gender of farm manager	Male	1	31	55
	Female	2	25	45
Wealth level	High	1	20	36
	Medium	2	36	64
Cattle management level	High	1	28	53
	Medium	2	25	47

The results of the logistic model concerning the decision whether or not to innovate are summarized in Table 57. Among the 56-calliandra farmers surveyed, 26 of them had made innovations, which were either direct or indirect. Twenty farmers had made indirect innovations, while seventeen had made direct innovations. Only eleven farmers had made both direct and indirect innovations. Direct innovations were those which farmers themselves claimed they have tried on their own, while indirect innovations were those practices which farmers undertook which were identified by the researcher/investigator and were not part of recommendation package. Farmers often do not see that they have innovated, for them experimentation is part of every day activities.

Of the selected desmodium farmers, none had made any direct innovations, while 11 had made indirect innovations, which were identified by the researcher. Due to the very small sample size (N= 24), it was not possible to determine the factors associated with innovation.

Table 57: Estimated parameters of the logistic model for assessing the factors associated with innovation in calliandra.

Variable	Coefficient	Standard error	Significance
Constant	3.97	2.70	0.14
Age	-0.04	0.03	0.22
Education	-0.22	0.10	0.03**
Rank of dairy enterprise	-0.26	0.39	0.51
Fodder experience	0.07	0.06	0.29
Gender (1)	0.32	0.69	0.64
Extension	-0.03	0.14	0.81
Wealth (1)	0.34	0.76	0.65
Cattle management level (1)	-0.40	0.77	0.60
Number of observations 56			

** Significant at p = 0.05

The logistic model of the decision to innovate identified only one variable to be significant in explaining farmer innovation concerning calliandra. The level of education of the farm manager (negative effect) was the only variable identified and it was significant at p = 0.05. Surprisingly, education appeared to reduce the amount of innovation a farmer made.

Student t-test was applied to compare innovators and non-innovators and the following variables, age, education, rank of dairy enterprise, extension and fodder experience. The average age of innovators was 55 years, compared to 56 years for non- innovators. The differences were not significant at p = 0.57 (t-test).

There were significant differences in the years of schooling between the innovators and non-innovators (p =0.01) (t-test). The average years of schooling of innovators was 6 years, while it was 9 years for non- innovators.

Also, there was also no significant difference between innovators and non-innovators and fodder experience, with the average years of fodder experience for innovators being 11, while it was 10 years for non -innovators. The difference was not significant (t-test, p = 0.60).

The average rank of the dairy enterprise was 1.6 for innovators and 1.8 for non-innovators. The difference was not significant at p =0.49 (t-test). Similarly, the differences in extension visits between the innovators and non-innovators were not significant (t-test, p =0.40). Extension visits for innovators averaged 1.70 times per year, while for non- innovators, it averaged 2.3 times per year.

Chi-square tests were employed to explore the differences between the innovators and non-

innovators and the following variables, gender of the farm manager, wealth levels and cattle management levels. The proportion of males who innovated was 48% while 44% of the females were innovators. However there were no significant differences between the two groups (Chi-square test, p= 0.74).

The distribution of wealthy categories among the innovators showed that 47% of low-medium wealth farmers innovated, while 45% of the high-wealth group innovated. The differences between the low-medium and high wealth groups were not significant (Chi-square test, p = 0.87).

We investigated the tendency for innovation to be associated with the management level of dairy enterprise; 50% of the high-management-level farmers were innovators, while 44% of the low-medium level farmers were innovators. However, the differences were not significant (Chi-square test, p=0.66).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The potential benefits of fodder legumes at the farm level have been demonstrated in the study. Integration of fodder legumes into the farming system would greatly contribute to the income of the smallholder dairy farmers and thus contribute towards poverty alleviation through improved animal performance (e.g. increase in milk yields) in addition of other unquantifiable benefits. Calliandra and desmodium can economically be used as a supplement resulting in substantial benefits. The net benefits of using fodder legumes as a supplement varied from scenario to scenario, however the differences observed were not significant (t-test).

Generally, calliandra farmers were getting higher net benefits than desmodium farmers, the differences were significant at $p = 0.01$ (t-test). This could be attributed to the impact of fodder legumes on milk, which was high for calliandra compared to desmodium. Even though calliandra was more profitable than desmodium, farmers did not want to replace calliandra with desmodium. They appreciate both legumes and want to continue growing both. The two species are thus complements in production and not substitutes. Probably reasons for preferring both are (1) farmers like to give their cows a varied diet rather than relying on a single species, and (2) planting more than one legume reduces the risk associated with a disease or pest eliminating one of the legume.

The findings also show that the net benefits in female managed farms did differ ($p>0.05$) from male managed ones. This finding highlights the importance of disaggregating farmer assessment data by gender. The findings also highlight the great potential of fodder legumes for enhancing the well being of poor and female households, as the legumes require less cash than dairy meal. But availability of planting material and information are also critical for promoting adoption, so that farmers can clearly see these benefits, as demonstration of positive economic impact would form the basis for increased adoption.

Most (93%) of the selected farmers had calliandra on their farms, compared to 40% who had desmodium. Thirty three percent of the farmers had both types of fodder (calliandra and desmodium). The two types of fodder are complements. The most important benefits of calliandra apart from being livestock feed were firewood, fertility improvement, improvement

in the health of the animal, improvement in the texture of milk and soil erosion control. Whereas fertility improvement, erosion control and weed control were the additional benefits of desmodium. Generally, calliandra was found to have more additional benefits than desmodium.

Farmers varied in the way they established fodder legumes. Calliandra was mostly established through seeds, which were mainly established first through nursery, while desmodium was established by use of vines (cuttings), which is easy as the farmers could easily relate to planting of sweet potato vines. Calliandra farmers have also adopted low cost establishment methods to replace or supplement the potted seedlings. Most farmers were using bare rooted seedlings possibly as a way of reducing labour and capital (cost of polythene bags and extra labour for planting in a nursery and transplanting). The use of bare rooted seedlings is cheaper than potted. Bare rooted seedlings require much less labour and cash outlay than potted seedlings yet perform just as well, as long as they are transplanted within a few hours after removal from the nursery. On the other hand non- cash resources requirements for the nursery production are significant including access to water and constant watering. Low cost establishment methods such as bare rooted seedlings should be encouraged to replace or supplement the potted seedling method as reducing capital and labour spent on establishment has important effect on profitability.

Also from the study, farmers planted calliandra in several niches (e.g. along hedges around the farm, intercropped with napier grass on contours or border bank) as compared to desmodium, which was mainly intercropped with napier grass on fodder banks or along the contours.

Farmers' management of the fodder legumes differed considerably from researchers' recommendations. Most innovations on management, which were done, involved calliandra as compared to desmodium. Some of the innovations mentioned by farmers included: drying calliandra and mixing with bran and using it as cattle or poultry feed, drying and mixing with indigenous fodder ('Muthatha or Mumbembu') and use it to feed goats, using the legume as compost when there is excess especially during rainy season. Other innovations identified include intercropping calliandra and desmodium. Because of the positive effect of the innovations, most farmers decided to continue with their 'newly' acquired knowledge depending on the circumstances e.g. if they had excess fodder. Researchers need to carefully

monitor farmers' own experiments. These changes (innovations) are presented as measures that researchers and farmers elsewhere can explore to help improve the adoption of fodder legumes.

Machete was found to be the common tool used for harvesting desmodium as it is harvested together with napier grass, while several types of tools were used when harvesting calliandra. These included shears and use of the hand to break the leaves.

Only one factor (education) was found to significantly influence the decision to innovate in calliandra.

5.2 Recommendations

Whereas the benefits of the legume have been demonstrated in this study, its actual potential benefits are still higher. The legumes have other benefits in addition of being used as a fodder. Despite all these, several important problems remain which include availability of planting material. Constraining the availability of planting materials may be lack of knowledge on the collecting and propagation of calliandra. Therefore encouraging the establishment of small-scale nurseries in different localities can solve the problem of seed supply. This should be backed up with sustainable extension activities on the potential of the legumes. In addition, farmer field visits should be encouraged. Seeing and discussing fodder legumes with farmers can be an effective means of promoting fodder planting and also provides forum where farmers can learn about its growth, management and uses.

The study identified one source of innovation, farmer-innovation (experiments designed and implemented by farmers). The innovations need to be encouraged and carefully monitored through continued interaction amongst farmers, extensionists and researchers, so that farmers' collective findings can be disseminated more widely to other farmers under similar conditions. Promoting farmer innovation through visits to other areas and amongst farmers is effective in making the farmers aware of local innovation and principles behind them. After returning home, participants will start informal experiments with the technology they have seen. Visits and exchange visits can be by farmer innovators visiting other innovators to learn from each other, ordinary farmers visiting farmer innovators to learn from their experience, and farmer innovators visiting other farmers to inform them and train them. Through shared experiences, their complementary strengths can be effectively exploited and integrated at a reasonable cost. Farmers should play a lead role in providing feedback to researchers on their experiences. It is

also important to monitor and encourage farmers to experiment with and modify the practices to their needs and circumstances. One of the ways of in which the formal research system can stimulate local innovations is by 'widening' the decision making horizon of farmers or increasing the information available to farmers on possible alternatives. As it has been noted that in cases where participatory research has been of collegiate or empowering type, farmers are thought to have increased their rates of experimentation. Farmer innovations and feedback have played an important role in modifying the extension messages shared with farmers.

REFERENCES

Abedin, Z. and Hague, F. (1991). Learning from Farmer innovations and innovation workshops: Experience from Bangladesh In Haverkort (ed.) 1991 Joining Farmers Experiments, Intermediate Technology Publishers, London, U.K.

Anaman, K.A. (1988). African Farm Management. Ghana Universities Press, Accra, Ghana

Angima, S.D., Stott, D.E., O Neill, M.K., Ong, C.K. and Weesies, G.A. (2002). Use of *calliandra*-Napier grass contour hedges to control erosion in central Kenya. *Agriculture Ecosystems and Environment.* Vol. 91 pp 15-23

Bunch, R. (1991). People centred agricultural Improvements. In: Haverkort, B (ed) Joining Farmers Experiments. Intermediate Technology Publishers, London, U.K

CIMMYT. (1988). From Agronomic Data to Farmer Recommendation: An Economics Training Manual. Completely revised edition, Mexico, D.F

CIMMYT Economics Program (1993). The Adoption of agricultural technology: A guide for survey design. CIMMYT, Mexico, D.F.

Dillon, J.I. and Hardaker, J.B. (1980). Farm management Research for Small farmer Development FAO Agricultural Services Bulletin FAO Rome, Italy

Doll, J.P. Orazem, F. (1984). Production Economics: Theory with applications John Willey and sons publishers.

Franzel, S. (2004). Financial Analysis of Agroforestry Practices. In Alavalapati, J.R.R and Mercer, D.E. (Eds). *Valuing Agroforestry Systems 9 –38.*

Franzel, S. (1999) Socio economic factors affecting the adoption of potential of improved tree fallows in Africa. *Agricultural systems 478: 305 –321*

Franzel, S. and Scherr, S.J. (eds). (2002). Trees on the farm: Assessing the adoption potential of Agro forestry practices in Africa, CABI, Wallingford, U.K

Franzel, S. Arimi, H. and Murithi, F. (2002) *Calliandra calothyrsus*: Assessing the early stages of adoption of a folder tree in the highlands of central Kenya. In Franzel, S. and Scherr, S.J. (eds.) 2002. Trees on the farm: Assessing the adoption potential of Agro forestry practices in Africa, CABI, Wallingford, UK

Franzel, S. Coe, R. Cooper, P. Place, F. and Scherr, S.J. (2001). Assessing the adoption potential of Agro forestry practices in sub- Saharan Africa. *Agricultural systems* Vol. 69: 37-62.

Guinand, Y. (1996). A Method To Select Farmers for on-farm agro forestry trials, based on wealth ranking. Afrena Report no. 102. ICRAF, Uganda.

GoK, (2004). Economic Survey, 2004, Government Printers, Nairobi, Kenya

GoK, (2002). National Development Plan (2002 –2008), Government Printers, Nairobi, Kenya

GoK, (2002a). District Development Plan (2002 –2008), Embu district, Government Printers, Nairobi, Kenya.

GoK. (1997). National Development Plan, Government printers, Nairobi, Kenya

Hoekstra, D.A. (1985). Choosing the discount rate for analysing agroforestry systems/technologies from a private economic viewpoint. *Forest Ecology and Management*.10: 177 –183.

ICRAF. (1998). Annual Report 1997, Nairobi, Kenya; ICRAF

ICRAF. (1996). Annual Report 1995, Nairobi, Kenya; ICRAF

ICRAF. (1995). Annual Report 1994, Nairobi, Kenya; ICRAF

Keil, A. (2001). Improved Fallows using leguminous trees in Eastern Zambia: Do initial testers adopt the technology? Unpublished MSc. Thesis, Georg-August University, Germany.

Kennedy, P. (1992). A Guide to Econometrics. Cambridge, Massachusetts, U.K.

Kibwana, O.T. (2000). Forging Partnership with Innovative Farmers in Tanzania. In: *ILEIA Newsletter,* July 2000 Vol. 16, No.2.

Lanyasunya, T., Onyango, T.A., Owango, M, Muriuki, K and de Jong, R (2000) Rear your own Heifers. KARI, Nairobi.

Mc Intire, J., Bourzat, D. and Pingali, A. (1992). Crop- livestock interaction in Sub- Saharan Africa, World Bank, Washington DC, USA

Moyo, S. and Ayuk, E.T. (2001). Costs and Benefits of Tree Fodder with Small Scale Dairy Farmers. In Bohringer, A. (ed.). Living With Trees in Southern Africa, Montfort Press

Mengich, E.K. (1994). Fodder Quality of 3 Agro forestry species. Unpublished MSc Thesis, University of British Columbia.

Michael, C.Y. (2001). Community assessment of local innovators in northern Ethiopia. In Reij, C and Waters-Bayer (eds) (2001). Farmer innovation in Africa: A source of inspiration for agricultural development. Earthscan publication. London U.K.

Miiro, D., Critchley, W., Van der Vall, and Wakuba, A. (2001). Innovation and impact: A preliminary assessment in Kabale Uganda. In Reij, C and Waters-Bayer (eds.) (2001). Farmer innovation in Africa: A source of inspiration for agricultural development. Earthscan publication. London U.K.

Mukras, M.S. (1993). Elementary Econometrics: Theory, Applications and Policy. East African Education Publishers. Nairobi, Kenya.

Murithi, F.M. (1998). Economic evaluation of the role of livestock in mixed smallholder farms of the central highlands of Kenya. Unpublished PhD Thesis, University of Reading, U.K

Murithi, F. M. Muthamia, J. N. Ouma, J. O. Micheni, A., Overfield, D., Ndubi, J., Gitari, J. and Maina, J. (2000). Socio-economic study of the uptake of Herbicide Technology in Maize based cropping system. *Report on a participatory Rural Appraisal in Embu District, Eastern Province, Kenya. NRI Report No. 2568.*

Mwangi, D.M. (2001). Potential benefits of integrating herbaceous legumes into smallholder dairy farms in central Kenya, KARI, Nairobi Kenya

Mwangi, D.M. and Wambugu, C. (2002). Forage legume technologies: Participatory experience with farmers and Community Based Organizations in central Kenya, KARI, Nairobi, Kenya.

Ndiritu, G.C. (1995). Livestock research needs in Sub-Saharan Africa – An East African View Point. In Gardiner P and Devendra C. (eds.). 1995. Global agenda for livestock research, proceedings of a Consultation, ILRI, Nairobi Kenya 18 –20 January 1995; ILRI, Nairobi, Kenya.

NRC (National Research Council). (1983). Under utilized Resources as Animal Feedstuffs. National Academy Press, Washington DC, USA

Nyaata, O.Z., Doward, P.T. Keatinge, J.D.H., and O'Neill M.K. (2000). Availability and use of dry season feed resources on smallholder dairy farms in Central Kenya, Kluwer Academy Publishers, Netherlands.

Omore, A., Muriuki, H., Kenyanjui, M., Owango, M., and Staal, S., (1999). The Kenya Dairy Sub-Sector. A Rapid Appraisal, MOA/KARI/ILRI, Nairobi, Kenya.

Ondieki, F.M. (1999). Socio economic factors influencing the adoption of agro forestry technology in Embu District, Kenya, Unpublished MSc Thesis, Oxford University, U.K

Paterson, R.T., Karanja, G.M., Roothaert, R.L., Nyaata, O.Z., and Kariuki, I.W. (1998). A Review of tree fodder production and utilization with smallholder agro forestry systems in Kenya. *Agro forestry systems* Vol. 41:2:181-199.

Paterson, R.T., Roothaert, R., Nyaata, O.Z., Akyeampong, E., and Hove, L. (1996). Experience with Calliandra calothyrysus as a feed for livestock in Africa. In Evans, D.O. (ed.) Proceedings of an international workshop on the genus Calliandra, 23 –27 January 1996.Winrock International, Bogotá, Indonesia

Pisanelli, A., Franzel, S., De Wolf; Rommelse, R. and Poole, J. (2002). The adoption of improved fallows in Western Kenya: Farmer practices knowledge and perception. *Agroforestry systems*.

Place, F. (1998). Issues Related to adoption management, use and impact of calliandra fodder feed sources. Embu farmer workshops, June 3 and 4 1998. ICRAF. Nairobi.

Reij, C and Waters-Bayer, A. (2001). Entering Research and development in land husbandry through farmer innovation. In Reij, C and Waters-Bayer (eds.) (2001). Farmer innovation in Africa: A source of inspiration for agricultural development. Earthscan publication. London U.K.

Rhoades, R. and Bebbington, A. (1991). Farmers as Experimenters. In: Haverkort, B (ed) 1991 Joining Farmers experiments. London, U.K.

Roothaert, R.L. and Franzel, S. (2001) Farmer's preference and use of local fodder trees and shrubs in Kenya. *Agro forestry systems* 52:3:239-252.

Roothaert, R., Karanja, G.M, Kariuki, I.R., Paterson, P., Tuwei, .P., Kiruiro, E., Mugwe, J. and Franzel, S. (2001). Calliandra for livestock. Technical Bulletin No. 1 ICRAF, Nairobi.

Rushton, J. (1996). Quantitative Methods for the Economic assessment of smallholder crop livestock farming system. Unpublished PhD thesis. University of Reading, U. K

Saad, N. (2002). Farmer Processes of Experimentation and Innovation: A Review of the Literature. Working Document, CGIAR System wide Program on Participatory Research and Gender Analysis

Spencer, D.S.C., Byerlee, D., Franzel, S. (1979). Annual costs, returns, and seasonal labour requirements for selected farm and non-farm enterprises in rural Sierra Leone. Working paper No. 27. Department of Agricultural Economics. Michigan State University. East Lansing, Michigan. USA.

Staal, S.J. Baltenweek, I. Waithaka, M.M, de Wolf, T. and Njoroge, L. (2002). Location and uptake: integrated household and GIS analysis of technology adoption and land use, with application to smallholder dairy farms in Kenya. *Agricultural Economics* 27:295-315

Upton, M. (1993). Livestock Productivity Assessment and Modelling. *Agricultural systems* 43:459-472

Upton, M. (1979). Farm Management in Africa. Oxford University Press. U.K.

Van der Veen, W. (1993). An economic Analysis on farms farming with fodder trees on dairy cows in Western, Kenya unpublished MSc. Thesis, Wagenigen Agricultural University, The Netherlands.

Wambugu, C. (2002). Calliandra calothyrsus: *Tree Management and Utilization*. Nairobi, ICRAF

Wambugu, C. Franzel, S., Tuwei, P., and Karanja, G. (2001). Scaling up the use of folder shrubs in Central Kenya, *Development in Practice* 11(4): 487-494.

Wanyoike, F.N. (2001). Dissemination and Adoption of improved fodder trees: The case of *Calliandra Calothyrsus* in Embu District, Kenya. Unpublished MSc Thesis University of Nairobi, Nairobi, Kenya

Winrock International. (1992). Assessment of Animal Agriculture in Sub-Saharan Africa. Little Rock, AR. Winrock International institute for Agricultural Development.

APPENDICES

Appendix 1. Checklist of activities and inputs associated with establishment of fodder seedlings in farmer nurseries in Embu district

I: Calliandra: Establishment and production costs

Farmer's Name: ..... Name of respondent
.....
Name of Enumerator ..... Date of interview
.....
Size of nursery (meters)..... ..... Approximate number of seedlings
.....

	Activity	**Persons involved** Male Female Labourer Children (<14)	**Time taken**	**Unit cost**	**Total cost**
4	**Nursery establishment** Ground levelling Carrying soil to the site Soil preparation/drawing lines Manuring/mixing soil with manure Filling plastic cube/sowing Constructing shelter/shade Other activities **Totals**				
5	**Nursery Maintenance** Watering 1st- 2 months - -Morning -Evening 3rd month onwards Weeding 1st 2nd **Total**				

6	Inputs (Nursery) Fertilizer Manure Seeds Wood for shade construction Branches for shading **Totals**	Quantity used	Unit of measurement	Unit Cost	Total Cost
8	**Production costs** Planting (No. of seedlings) Weeding 1st 2nd 3rd **Totals**	**Person involved**	**Time Taken**	Unit cost	Total Cost
9	**Inputs (Planting)** Fertilizer Manure **Totals**	**Quantity used**	**Unit measurement**	Unit Cost	Total cost
10	**Labour** If hired labour how are they paid Wage rate – rate/day Contract – Rate/area				

II: *Desmosdium*: Establishment and Production costs

Farmers name: ..... Name of Respondent: .....

Name of Enumerator:..... Date of interview:

Area of *desmodium*: .....

Inputs	Quantity Used	Unit of measurement	Unit cost	Total cost
Vine/seeds				
Fertilizer				
Manure				
Activity	Persons involved	Time taken	Unit cost	Total cost
Planting (Amount of vines/seed)				
Weeding 1st 2nd				

Labour

If hired labour, how are they paid?

Wages rate ..... per day

Contract ..... per area

Appendix 2.Questionnaire

A: Farmer Questionnaire

Socio-Economic Analysis of fodder legumes: The case of Calliandra and Desmodium in smallholder Dairy farms of Embu district, Kenya.

Fodder Type _____

Questionnaire No._____

1. Name of the farmer_____ Location _____ Division _____
2. Name of respondent_____
3. Relationship of respondent to farmer_____
4. Name of enumerator_____
5. Date of interview_____

Basic information

6. Distance from main road _____
7. Distance from nearby marketing centre _____ Name of Centre_____
8 Farm size_____ ha/acres, other plots, size; _____ ha/acres
9 Who does day-to-day management of the dairy enterprise? 1=husband 2=wife 3= permanent hired labour 4= other _____
10 Educational level of farmer in years_____
11 Age of the farmer _____ (years)
12 What are your most important (profitable) in terms of cash & food generation activity at your farm? (Ranking 1st, 2nd,etc.)

Enterprise	maize	coffee	tea	dairy	poultry	fruits	other (specify)
Rank							

13 Number of coffee trees in the farm_____

Fodder planting, management and feeding

14 How many calliandra trees / area of Desmodium do you have on your farm _____ Desmodium _____
15 When did you plant? Calliandra_____(year); Desmodium _____(year)
16 Where have you planted your fodder trees?
Calliandra 1= Boundary (internal/ external). 2= Pure stand. 3= intercropped with Napier grass on contours. 4= Intercrop with Napier grass on fodder banks 5= intercropped with other crops
Desmodium 1= Boundary (internal/ external). 2= Pure stand. 3= intercropped with Napier grass on Contours. 4= Intercrop with Napier grass on fodder banks 5= intercropped with other crops
17 What pruning\ cutting technique do you use?
Calliandra 1= cutting with a panga\ machete. 2= breaking by hand. 3= using secateurs\ shears 4= other (specify) _____
Desmodium 1= cutting with a panga\ machete. 2= breaking by hand. 3= using secateurs\ shears 4= other (specify)_____
18 At what height do you prune calliandra? _____ (Feet/m)

19 How many times do you harvest the same tree/a plot of desmodium in a year?
Calliandra_____. Desmodium _____

20. How long do you stay before the next harvesting cutting the same tree/ plot of desmodium?
Calliandra; Dry season _____month (s)/Weeks Wet season _____month (s)/Weeks
Desmodium; Dry season _____month (s)/Weeks Wet season _____month (s)/Weeks

21 What livestock type do you feed calliandra\ desmodium?
Calliandra: 1=cows. 2= heifers. 3= mature males. 4= calves. 5= goats. 6= sheep. 7= poultry. 8=other (specify)_____
Desmodium: 1=cows. 2= heifers. 3= mature males. 4= calves. 5= goats. 6= sheep. 7= poultry. 8=other (specify)_____

22 Do you feed Calliandra/ desmodium to your dairy cattle throughout the year? Calliandra 1=yes 2=no Desmodium 1=yes 2= no

23 If no, have you been feeding the last three months? Tick boxes,

Calliandra

JAN	FEB	MAR

Desmodium

JAN	FEB	MAR

24 Have you used any commercial feed in the last three
If yes specify type.
.....
.....

25 Do you feed dairy meal to your dairy cattle throughout the year? 1=yes 2=no

26 If no, have you been feeding with dairy meal for the last three months? Tick boxes

JAN	FEB	MAR

27 If you are feeding dairy meal to your animals, how much dairy meal do you give a cow per day? _____

28 What is the cost of buying dairy meal? _____ Ksh per bag

29 What is the cost of transporting dairy meal to the farm? _____Ksh per bag

30 How do you feed calliandra\ desmodium in relation to the dairy meal?
1= supplement. 2= substitute. 3= partial substitute

31. Do you have any lactating cows 1= yes 2= no

32 If yes did you feed calliandra, desmodium, and dairy meal in the last three months?

Calliandra

JAN	FEB	MAR

desmodium

JAN	FEB	MAR

Dairy meal

JAN	FEB	MAR

33 When do you feed calliandra / desmodium to your cows? Calliandra 1= during milking 2= after milking
3 =other (specify)
Desmodium 1= during milking 2= after milking 3= other (specify)_____

34 How many minutes it usually take to cut, carry and chop calliandra\ Desmodium per day?
Calliandra_____Desmodium_____

35 Do you chop calliandra\ desmodium before feeding? *Calliandra* 1= yes 2= no
Desmodium 1=yes 2= no

36 What type of tool do you use Calliandra 1= panga 2= chaff cutter 3= other (specify) _____
Desmodium *1* = panga 2= chaff cutter 3= other (specify)_____

37 How do you feed the animals with calliandra\ desmodium after cutting?
Calliandra 1= when fresh 2= after wilting. 3= when dry [not conserved] 4=Conserved [hay/ silage]
Desmodium 1= when fresh 2= after wilting. 3= when dry [not conserved] 4=Conserved [hay/ silage

38 If you are feeding fodder trees and dairy meal to your cows, what are the advantages of fodder trees? Compared to dairy meal?
Calliandra; 1= readily available 2= cheap 3= other [specify]
Desmodium; 1= readily available 2= cheap 3= other [specify]

39 If you are feeding fodder trees to your cows, what are the disadvantages of fodder trees?
Calliandra; 1= None 2=requires a lot of labour 3= other (specify)_____
Desmodium; 1= None 2=requires a lot of labour 3= other (specify)_____

40 [a] Have you tried any thing new on your own apart from recommendations? 1= yes 2 = no
[b] If yes, [specify]
.....
.....
[c] What happened?
.....
[d] What did you decide?
.....
[e] What are its advantages?.....
.....
Disadvantages.
.....

41 What constrains limit Calliandra/ Desmodium expansion in your farm?
Calliandra _____
Desmodium _____

Livestock production

42 What type and number of animals do you keep on your farm and how many of each?
1= cows _____ 2= Heifers_____ 3= Mature bulls_____ 4 =Calves_____
5= Sheep_____ 6= Goats_____ 7= Poultry_____ 8= Pigs_____

43 What type of dairy cattle breeds do you have? 1= Cross breed; chest girth (cm)_____
2= local _____chest girth (cm)_____

44 What method do you use to raise various types of livestock? 1= in an enclosure 2= free grazing
3 = tethering

45 If 1, what type of enclosure is used to house your cattle? 1= Roofed with concrete floor.
2= Roofed and no concrete floor 3= Open and no concrete floor. 4= Concrete and no roofing

46 Do you use hired labour for any cattle production activities? 1= yes. 2=no

47 If yes, how is he paid? 1=casual (amount/day) 2= monthly/contract amount/month

48 What major capital goods, implements are there on the farm? 1= owns 2=does not own

Water tank _____ sprayer_____ chaff-cutter_____

49 Do you spray/ dip your animals? 1= yes 2= no

50 What constrains limit livestock expansion? Rank the constrains

Constraint	Rank
Lack of capital	_____
Shortage of land	_____
Lack of market for milk	_____
Lack of labour	_____
Other (specify)	_____

51 How much milk do you produce per day?_____

Morning	Evening	Total

52 No .of milking cows _____

53 Have you been selling any milk in the last one-year? 1= yes. 2= no.

54 which months of the year were the price lowest? _____

55 What was the price? Ksh_____ Per litre/bottle/kg

56 Which months of the year was the price the highest? _____

57 What was the price? _____ Per litre/bottle/kg

58 Are you selling milk currently? 1= yes. 2= no.

59 What is the price? _____ Per litre/bottle/kg

Impacts of fodder shrubs (*Desmodium\Calliandra*)

60 How much calliandra / desmodium do you give to a cow per day? _____Kgs, cut and Weighed

61 What impact has calliandra/ desmodium had on milk production Calliandra; 1= do not know 2= increased 3= no effect 4= decreases Desmodium; 1= do not know 2= increased 3= no effect 4= decreases2

62 If 2, how much/ cow/day Calliandra _____lts/Kgs/cow/day, Desmodium _____lts/Kgs/cow/day

63 If you are selling milk, what do you do with additional money earned from using calliandra or desmodium?

Use	Rank
Pay school fees	_____
Health care	_____
Purchase of every day commodities	_____
Other (specify)	_____

64 What other impacts has desmodium/ calliandra had apart from increase in milk?

Calliandra .....

.....

Desmodium .....

.....

65 Have you observed any negative effect of calliandra and desmodium? 1=Yes 2=No.

If yes, specify;

Calliandra .....

.....

Desmodium .....

.....

Extension activities

66 How many times have you received advice/ visits from extension officer in the last one-year?

_____

67 Level of wealth (look at the type of house, Number of coffee trees, and type of cattle breeds)

For the Enumerator after the interview

1. Cattle management level
   1=High 2= Medium 3= Low
2. Wealth level (number of grade cattle, number of coffee trees, type of housing)
   1=High 2= Medium 3= Low
3. Observe type of housing (wall) .....

Wealth Ranking Table

Indicator	1= Most Wealthy	2= Medium Wealthy	3= Less Wealthy
1. Grade cattle ownership	>2	1-2	No grade cattle
2. Coffee ownership (number of bushes)	>500	100-500	<100
3. Type of housing	Stone	Timber	Grass thatched/Mud walled

Source: Adapted from Murithi *et al.,* (2000)

B: Market survey questionnaire

1. Price of dry maize per 90 Kg bag.....
2. Price of beans per 90 Kg bag.....
3. Coffee prices (factory) per Kg.....
4. Maize seed prices.....Unit.....
5. Bean seed prices.....Unit.....
6. Fertiliser cost (DAP).....Unit.....
7. Fertiliser cost (CAN).....Unit.....

.....

Desmodium .....

.....

Extension activities

66 How many times have you received advice/ visits from extension officer in the last one-year?

_____

67 Level of wealth (look at the type of house, Number of coffee trees, and type of cattle breeds)

For the Enumerator after the interview

1. Cattle management level
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Wealth Ranking Table

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B: Market survey questionnaire

1. Price of dry maize per 90 Kg bag.....
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3. Coffee prices (factory) per Kg.....
4. Maize seed prices.....Unit.....
5. Bean seed prices.....Unit.....
6. Fertiliser cost (DAP).....Unit.....
7. Fertiliser cost (CAN).....Unit.....

Appendix 3 Relationship in cattle between chest girth in cm and live weight in kg

Girth Size (cm)	live weight (kg)	Girth Size (cm)	live weight (kg)	Girth Size (cm)	live weight (kg)	Girth Size (cm)	live weight (kg)
45	15	85	59	125	170	165	372
46	16	86	61	126	174	166	378
47	17	87	63	127	178	167	385
48	18	88	65	128	182	168	392
49	19	89	67	129	186	169	399
50	20	90	69	130	190	170	406
51	21	91	71	131	194	171	413
52	22	92	73	132	198	172	420
53	23	93	75	133	202	173	427
54	24	94	77	134	206	174	435
55	25	95	79	135	210	175	443
56	26	96	81	136	214	176	451
57	27	97	83	137	218	177	459
58	28	98	85	138	222	178	467
59	29	99	87	139	226	179	475
60	30	100	89	140	230	180	483
61	31	101	92	141	235	181	491
62	32	102	95	142	240	182	500
63	33	103	98	143	244	183	508
64	34	104	100	144	248	184	516
65	35	105	103	145	252	185	525
66	36	106	106	146	256	186	534
67	37	107	109	147	260	187	543
68	38	108	112	148	264	188	552
69	39	109	115	149	268	189	561
70	40	110	118	150	272	190	570
71	41	111	121	151	276	191	580
72	42	112	124	152	280	192	590
73	43	113	127	153	285	193	600
74	44	114	130	154	290	194	610
75	45	115	134	155	295	195	620
76	46	116	137	156	301	196	631
77	47	117	140	157	307	197	642
78	48	118	143	158	313	198	653
79	49	119	146	159	319	199	664
80	50	120	150	160	325	200	675
81	51	121	154	161	345	201	686
82	53	122	158	162	353	202	697
83	55	123	162	163	360	203	708
84	57	124	166	164	366	204	720

Source: Lanyasunya *et al.*, (2000)

Appendix 4. Exchange ratios for livestock in Tropical Livestock Units (TLU) based on live weight

Body weight (kgs)	Tropical Livestock Units
5	0.05
10	0.09
15	0.12
20	0.15
25	0.18
30	0.20
35	0.23
40	0.25
45	0.28
50	0.30
60	0.34
75	0.41
100	0.50
125	0.59
150	0.68
200	0.85
250	1.00
300	1.15
350	1.29
400	1.42
450	1.55
500	1.68
600	1.93
700	2.16

Source: Adapted from Upton, (1993)

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