DETERMINANTS OF ADOPTION OF FORAGE TECHNOLOGIES AMONG PERI-URBAN DAIRY FARMERS IN THE SEMI-ARID REGION OF SOUTH EASTERN KENYA

BY

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DECLARATION

I declare that this thesis is my original work and has not been submitted or presented for examination, in part or as a whole, for any academic award in any other University.

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Signature Mr. Silvester K. Mutavi Date

(A56/KIT/20006/2011)

APPROVAL

This thesis has been submitted with our approval as University supervisors.

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DEDICATION

I dedicate this thesis to my Lord for giving me good health despite the many challenges during the study period. I further dedicate it to my father's family, my sons, Frazer Koli and Eugene Kiangi, and my dear friends, who have all been and continue to be a source of encouragement in my life.

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ABSTRACT

Semi-arid peri-urban environment holds great potential for dairy development to meet the high demand for milk and become a livelihood support strategy. In support for dairy production, forage technologies were promoted among dairy farmers in order to improve the performance of the sector and contribute to poverty reduction. However, the level and determinants of adoption of selected forage technologies in relation to dairy production is still unknown. To address this, 150 dairy farmers, with 120 purposively selected from a list of dairy farmers and 30 additional dairy farmers randomly selected in the peri-urban areas of Machakos and Wote Towns. The primary data collected using semi-structured questionnaire were coded, organized and analysed using descriptive statistics to generate means, frequencies, percentages and chi-square tests. In addition, a logistic regression model was used to evaluate the determinants of adoption of selected forage technologies among dairy farmers in the study areas. The findings of this study show that the levels of adoption of the forage technologies among dairy farmers were low at $p<0.05$. Age, gender and family size of the household head were found to be insignificant in influencing adoption of most forage innovations. Access to extension, expected milk yield, land tenure and years of experience in dairying greatly influenced adoption of fodder crops; land tenure system, type of feeding and access to extension influenced adoption of *tumbukiza* method; years of experience of dairying, access to extension and expected milk yield greatly influenced adoption of conservation technologies; type of feeding and years of experience dairying influenced adoption of hay barn technology while education and experience of the farmer greatly influenced adoption of feedstuff chopping. Establishment of improved fodder crops, use of *tumbukiza* technology, use of hay and silage conservation technique, intensifying extension in form of farm visits, improvement of water supply and improvement of access of affordable artificial insemination services and increased availability of skilled artificial inseminators were identified as mitigation measures to enhance adoption and continued use of selected forage technologies and improve dairy production in semi-arid regions of south eastern Kenya.

Key words: Adaption, Alleviation, Constraints, Food security, Innovation, Livelihood, Peri-urban environment, Poverty, Vulnerable groups.

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
AI	Artificial Insemination
ASALs	Arid and Semi-Arid Lands
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ASCU	Agricultural Sector Coordination Unit
asl	above sea level
CBC	Cross Bred Cows
CBO	Community Based Organization
CGIAR	Consultative Group on International Agricultural Research
DFID	Department for International Development
ECA	East and Central Africa
EPZ	Export Processing Zone
ET	Embryo Transfer
FAO	Food and Agriculture Organization
FGD	Focused Group Discussion
GDP	Gross Domestic Product
GoK	Government of Kenya
HB	Hay Barn
IFAD	International Fund for Agricultural Development
IMF	International Monetary Fund
KALRO	Kenya Agricultural Livestock Research Organization
KARI	Kenya Agricultural Research Institute
KDB	Kenya Dairy Board
KII	Key Informant Interview
LL	Log-likelihood
LM	Lower Midlands
MoF	Ministry of Finance
MDG	Millennium Development Goal
NALEP	National Agriculture and Livestock Extension Programme

NGO	Non-Governmental Organization
RoK	Republic of Kenya
RUAF	International Network of Resource Centres on Urban Agriculture and Food Security
SPSS	Statistical Package for Social Sciences
SRA	Strategy for Revitalizing Agriculture
SWOT	Strengths, Weaknesses, Opportunities and Threats
TM	Tumbukiza Method
UN	United Nations
UM	Upper Midlands
USAID	United States Agency for International Development

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND INFORMATION

Globally agriculture provides livelihood support for the rural people more than any other industry (FAO, 2003) and is the main source of livelihood for the majority of people in developing countries. Therefore growth in agricultural production and productivity is fundamental in raising income and meeting food security, which, as noted by Amwata (2013), prevails when the aggregate food production in a year is enough for the existing population at any given time of the year. However, farming communities in the Africa are becoming more vulnerable as climate and increasingly variable weather are reducing agricultural productivity (CGIAR, 2014).

Kenya relies heavily on the agricultural sector for income generation, employment and foreign exchange. The sector accounts for 30% of Gross Domestic Product (GDP) and 75% of employment and 90% of the rural poor relies on agriculture (Orindi *et al.,* 2006). In addition, the sector also accounts for 65% of Kenya's total exports and therefore, the growth of the national economy is highly correlated to growth and development in agriculture. However, Kenya's agriculture is mainly rain-fed and highly vulnerable to climate change and variability. The rains are low and unreliable in most parts of the country. For example, in the last 50-100 years, Kenya's temperature has increased and in turn reduced the amount of arable land, resulting into an increase of size of arid and semi-arid lands (ASALs). Therefore, more than 80 % of the Kenyan land mass (582,646km^2) is categorized as ASALs with an annual rainfall average of 400 mm (Matiru, 2004). The agricultural production is constrained by the inadequate rains and frequent droughts and crops fail in one out of every three seasons (Orindi *et al.,* 2006; Recha *et al*., 2013). The frequency and severity of these climate shocks are increasing and likely to lead to major food crises if adaptive and resilient measures are not adopted by the farmers (CGIAR, 2014; Amwata *et al*., 2015).

Livestock is one of the key sub-sectors of agriculture. It contributes over half of the value of the global agricultural output (Swanepoel *et al*., 2011), supports rural livelihoods, creates employment, and reduces poverty as well as strengthening the household economy. Waters-Bayer and Letty (2010) and Swanepoel *et al.,* (2011) further noted that livestock keeping allow resource-poor households and vulnerable groups especially women, who do not own land, to accumulate assets, like small animals. In addition, dairy farming in Kenya is an essential high-income generating agricultural activity. It contributes about 3.5% to the GDP (KDB, 2007; Kinambuga, 2010). Further, the dairy sector also supplies milk to the households while the surplus milk is marketed.

The World Bank (2008) and UN Habitat (2002) have projected a rapid rise in the urban population in all developing countries, like Kenya. This high urban population, with higher average household incomes (Delgado *et al*., 1998), helps in fueling the demand for livestock products, like milk and meat. In contrast, the rapid urbanization has not been accompanied by equitable economic growth in peri-urban areas (Kodhek, 1999). This has resulted in increased poverty and food insecurity in semi-arid peri-urban lands of Kenya (Guendel, 2002).

The livestock farmers have adopted dairy farming as a livelihood and food security strategy (Kang'ethe *et al.,* 2002). This is attributed to the high demand for milk in the urban and peri-urban areas (RUAF, 2003), increased urbanization and favourable infrastructure. Livestock production is essential as it supplies milk, reduces poverty, provides employment and improves standards of living of the rural populace (RUAF, 2003). However, dairy farming is relatively low (Njarui *et al.*, 2011) in the semi-arid peri-urban environment despite the high potential for dairy development. In addition, despite these great benefits, FAO (2001) acknowledges that the peri-urban and urban dairy production system is largely underestimated by urban policy makers.

Dairy farming, especially in the semi-arid peri-urban environment of south eastern Kenya, is faced with many constraints such as climate change (shift in meteorological conditions, like rainfall, temperature and humidity, that last for a long period of time usually centuries) and variability - short-term fluctuations of climatic elements such as temperature and rainfall happening from year to year (Tasokwa, 2011; Wasonga *et al.*, 2010; Amwata, 2013); inadequate feedstuffs and water; decline in land holdings due to fragmentation of land (Amwata, 2004; Wasonga *et al.,* 2010); environmental degradation; limited adoption of new promising technologies and innovations; poor extension and veterinary services; inadequate funding and inefficient marketing services and low productivity (IFAD, 2009). This has contributed to milk insufficiency (Kinambuga, 2010). The introduced exotic dairy cattle and Cross-Bred Cows (CBC) in the ASALs, referred to as dairy cattle in this study, justify the need to adopt production-enhancing and forage innovations and better ways of stimulating milk production to meet the ever increasing demand for milk.

Given the importance of agriculture and livestock to the Kenyan economy, the government has been proactive and has spear-headed several interventions in the sector. For example, the Strategy for Revitalizing Agriculture (SRA) was launched in 2004 to transform Kenya's agriculture into a profitable, commercially-oriented and internationally and regionally competitive economic activity that provides high-quality, gainful employment to Kenyans. The SRA also gave policy direction and actions that needed to be taken in each agricultural subsector such as dairy to achieve the vision. Also in 2006, the Agricultural Sector Coordination Unit (ASCU) was established to ensure coordination of issues across ministries. These, coupled with development of comprehensive programmes in agriculture, have played a critical role in promoting agricultural growth in Kenya including the ASALs. In addition, Kenya Agricultural Livestock Research Organization (KALRO), formerly Kenya Agricultural Research Institute (KARI) and Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) have been promoting climate smart agricultural technologies and innovations in the peri-urban environments of Makueni and Machakos Counties among dairy farmers since 2010. Despite these many initiatives, more still need to be done especially the use of science and technological innovations to improve dairy development in the semi-arid areas in south eastern Kenya especially in providing adequate feeds in terms of quality and quantity.

Faced with myriad of constraints, the dairy farmers need to adopt promising dairy and forage technologies especially in utilizing the limited forage resources in ASALs. This remains critical for increased milk production and improvement of the performance of dairy industry for economic growth (Tangka *et al.,* 1999). Some of the innovations include: improved breeds and breeding techniques to increase milk productivity, improved fodder crops to increase forage production, micro-water catchments (like *tumbukiza* pits) to increase moisture and nutrients availability, chopping of feedstuffs to enhance utilization, crop residue to ensure adequate feedstuffs, conservation practices to store excess forage and prevent contamination, hay barn (HB) for proper storage, water harvesting techniques for adequate water supply and milk value addition to enhance marketing of milk and reduce its perishability.

This study was a follow-up to assess the adoption of selected forage technologies promoted by KALRO and ASARECA including establishing the factors for adoption of these technologies among the peri-urban dairy farmers in Machakos and Makueni Counties of south eastern Kenya.

1.2 PROBLEM STATEMENT

Semi-arid peri-urban environment holds great potential for dairy development due to the high milk demand, favourable infrastructure and agricultural support services. For many years, dairy farmers in semi-arid regions of Kenya have evolved ways, like growing of fodder crops and utilization of crop residues, to increase milk sufficiency and improve their livelihoods through income generated from milk sales. However, not all evolutions have shown remarkable successes, thus the supply of milk in the semi-arid regions is below its demand especially in the dry season. In order to increase production of quality and quantity of milk with minimal costs and the dairy farmers to become resilient, many forage technologies have been developed and disseminated to the dairy farmers for adoption. However, the extents of adoption of the forage technologies and their contribution on dairy performance and farmers' livelihood have not been documented. Therefore, the goal of this study was to shed light on the extent of adoption of selected forage technologies, challenges and the determinants for the adoption of these technologies in the peri-urban areas of Wote and Machakos Towns in the South Eastern Kenya. This information is fundamental in promoting the relevant and most promising forage technologies for the dairy production in the peri-urban areas in the semi-arid regions of South Eastern Kenya while also identifying opportunities for up-scaling. In addition, mitigation measures will be offered to make the dairy farmers more resilient in their livelihoods in these semi-arid regions of South Eastern Kenya.

1.3 JUSTIFICATION OF THE STUDY

The ASALs of Kenya are characterized by low and erratic rainfall, infertile soils, poor drainage that limits primary productivity especially forage resources. This is further exacerbated by climate change and variability which increases the uncertainty of forage resources in these dryland ecosystems. According to Amwata (2013), majority of the population in ASALs are heavily dependent on rainfall for the agricultural activities. Further, Amwata (2013) noted that climate and livelihoods are linked and when the climatic conditions (shifts in seasonal characteristics, such as alternating wet and dry conditions together with their associated effects) worsen, livelihoods sustainability is affected. This places an additional strain on dairy production, food security, water availability and viability of rural livelihoods in the semi-arid regions of south eastern Kenya. Therefore, the adoption of forage technologies and innovations is a pre-requisite for improved dairy transformation and poverty reduction in semi-arid regions.

With the climate change and variability, the sparse forage resources will jeopardize dairy production, if promising forage production-enhancing and labour saving technologies are ignored and neglected. This study aims to assess the extent of adoption of promoted forage technologies and their contribution to dairy performance in the peri-urban environs of Machakos and Wote Towns. These two sites selected for the study were those in which KALRO and ASARECA have been promoting climate smart agricultural technologies since 2010, yet the impacts of these technologies have not been evaluated to prioritize these technologies based on their performance.

In addition, the study also identified the challenges and factors influencing adoption of the selected forage technologies in these semi-arid regions of South Eastern Kenya. This information will act as a basis for future adaptation and resilient measures needed to support and sustain livelihood activities in the study areas. The results of this study provide information that can be used to formulate strategies to improve the peri-urban dairy production system in semi-arid regions of South Eastern Kenya. Further, the generated information will also guide the choice of appropriate technologies and targeting of farmers for intervention on dairy sector.

1.4 OBJECTIVES OF THE STUDY

1.4.1 Broad Objective

The main objective of this study was to investigate the extents of adoption of forage technologies and innovations and establish the factors influencing their adoption among peri-urban dairy farmers in the semi-arid regions of South Eastern Kenya.

1.4.2 Specific Objectives

The specific objectives addressed by this study were to:

i) Determine the extents of adoption of selected forage technologies among peri-urban dairy farmers in the peri-urban areas of Wote and Machakos Towns.

ii) Assess the challenges and threats affecting adoption of selected forage technologies among peri-urban dairy farmers.

iii) Determine the factors influencing adoption of selected forage technologies among peri-urban dairy farmers.

1.5 RESEARCH QUESTIONS

The study sought to answer the following questions:

i) What are the extents of adoption of selected forage technologies and innovations adopted by peri-urban dairy farmers in Wote and Machakos Towns?

ii) What are the challenges and threats affecting the adoption of selected forage technologies among peri-urban dairy farmers in Wote and Machakos Towns?

iii). What factors influence the adoption of selected forage technologies among peri-urban dairy farmers in Wote and Machakos Towns?

1.6 LIMITATIONS OF THE STUDY

Some households were unwilling to participate in the study due to the fact that many studies have been carried out in the past with no feedbacks to the farmers. Thus most of them complained that they had been misused for long. However, after being convinced, they agreed to participate in the survey. This affected the interviewing schedule and data collection exercise in November 2012 – March 2013.

In addition, at the time of the study, the two counties were experiencing presidential and parliamentary election campaigns and heavy rains. It was observed that some households' members and key informants were unavailable at the scheduled time of the interviews. Thus, many visits were made in the areas of study to ensure that all the households selected were interviewed. Therefore, the administration of questionnaires took more time than planned.

1.7 ASSUMPTIONS OF THE STUDY

Three assumptions were made in this study:

i) The information obtained was assumed to be accurate. This is because most responses were based on recall criteria rather than from written records.

ii) The respondents had no doubts and were not suspicious about the intentions of the study, thus they gave relevant information.

iii) The introduction of production-enhancing and forage technologies was unbiased and thus it was uniformly carried out in the targeted locations by the relevant stakeholders.

CHAPTER 2

LITERATURE REVIEW

2.1 CHARACTERIZATION OF THE MILK PRODUCTION SYSTEM IN KENYA

2.1.1 History and Overview of Dairy Industry in Kenya

Exotic dairy cattle were first introduced to Kenya from Europe by white settlers in 1920 and established in the Kenyan highlands for commercial dairying (Omore *et al*., 1999; Kavoi *et al*., 2009). However, indigenous Kenyans were not involved in commercial dairying until the mid-1950s (Muriuki, 2003). After independence, most dairy cattle were transferred by the government to the indigenous people, marking the beginning of small scale domination of the dairy industry (FAO, 2011).

Dairy production in Kenya is divided into small scale and large scale. The differences between the two dairy systems are in their size of operation, level of management and use of inputs (Muriuki, 2003). The small scale dairying (operation is small in size – 2-3 dairy cows owned by a household and low level of management) is the most popular as it's the one affordable by most resource-poor farmers and constitutes 70-80% of the total dairy subsector (Ngigi, 2004; IFAD, 2006; Kinambuga, 2010). The large scale commercial dairying is practised by relatively high income individuals or institutions in the Kenyan highlands.

The dairy industry utilizes exotic breeds, like Holstein-Friesian, Aryshire, Guernsey, Jersey and Sahiwal and CBC – generally referred in this study as the dairy cattle. The dairy cattle contribute virtually all the milk that is marketed while the milk produced by other livestock species, like goats, is generally consumed at source. However, there has been a fluctuating trend in milk production over the last decade - which threatens household food security and income sources especially in the semi-arid areas (KDB, 2009). Further, it is noted that there are signs that the dairy industry is unable to continue satisfying demand of milk from the growing population (RoK, 2007), leading to importation of fresh and powdered milk from Uganda to Kenya.

2.1.2 Distribution of Dairy Cattle, Milk Production and Productivity in Kenya

The dairy cattle are mainly concentrated in central highlands, central Rift Valley, central eastern regions and western highlands of the country, (RoK, 2007), which have favourable climate for commercial production (Kavoi *et al.*, 2009). This explains why most milk is produced from these areas. Milk glut occurs in these areas during the wet seasons and most milk goes into waste due to inefficient marketing systems or limited milk value addition methods and storage.

Dairy experts advised that dairy cattle have higher nutritional demand and poor adaptability in the ASALs and they perceived low production performance under smallholder management conditions (Rege, 1998). Therefore, the dairy experts recommended the upgraded zebu breeds to be reared in ASALs due to their low food requirements and adaptations to climatic conditions in ASALs (SDP, 2009). Bebe *et al.,* (2003) in a study on smallholders systems in the Kenya central highlands revealed that small scale holders in the ASALs have shown preference for high dairy cattle breeds as a key component of their improved milk production strategies. This is contrary to the dairy experts view and advice to the livestock farmers in the ASALs in Kenya. However, through the slow process of dairy cattle technology diffusion from the Kenyan Highlands (Bebe *et al.*, 2003), small scale exotic dairy production has been established in the semi-arid areas since the mid-1980s especially those adjacent to urban centres to meet the high milk demand in these areas against expert's idea that they can't survive in the ASALs (Kavoi *et al.,* 2009).

Recent studies have revealed that the concentration of dairy cattle has remained low in these areas. For example, Njarui *et al*., (2012**)** noted that the concentration of the exotic cattle in semi-arid areas in agro-ecological zone (AEZ) IV is as low as 3-4 cattle per household. This is attributed to low forage availability, unreliable sources of affordable dairy cattle, inadequate quality feedstuffs and water, high temperatures and frequent windy conditions (Kavoi *et al.*, 2009) which are deterrent to dairying in the ASALs.

Nicholson *et al.*, (2004) in a study of household-level impacts of dairy cow ownership in coastal Kenya showed that acclimatization of dairy cattle and modification of the farm environment such as on-farm water supply, establishment and production of improved forage improves performance of dairy cattle in coastal semi-arid areas of Kenya.

Kavoi *et al*., (2009) conducted a study on production structure and derived demand for factor inputs in smallholder dairying in Kenya revealed that construction of feed storage structures have facilitated introduction and intensification of dairy cattle in the dry AEZ IV zones. This is supported by findings of Trail *et al*., (1981) who studied milk potential contribution of Sahiwal cattle in Africa and those of Ngigi (2005) in a study of smallholder dairying in Eastern Africa. Njarui *et al*., (2011) and Kabirizi *et al.*, (2013) noted that stall-fed dairying improves the livelihoods of rural women as they have access to livestock keeping.

The Holstein-Friesian breed is dominantly kept under semi-intensive system (80%) and the dairy cows remains the dominantly kept cattle in the households in the ASALs (Njarui *et al*., 2011**)**. Also, Njarui *et al*., (2012) observed that milk productivity of these animals is low in the ASALs and ranged between 3.0 litres /cow /day during the dry season to 9.0 litres /cow/day during the wet season.

Further, due to land–use change, decline in land size, high demand for milk and effects of climate change, the dairy farmers have been modifying the environmental conditions and improving their management practices necessary for the habitation and increased milk production of these introduced dairy cattle. Kinambuga, (2010) noted that smallholder dairy farming is gradually being improved in the semi-arid regions of eastern Kenya to supply the much needed milk. Despite this emerging trend in dairy production, many studies have emphasized on influences of socio-economic factors on rural agricultural livelihoods in the ASALs (Amwata, 2004 and Ngugi and Nyariki, 2005) paying little attention to dairy production. Thus the extent of adoption and performance of the forage technologies and investigation of the factors influencing selected forage technologies and innovations, including factors influencing their adoption is ignored especially the links between the technologies and dairy performance.

2.1.3 Importance of Dairy Industry in Kenya.

Dairy farming is a major employer in Kenya and a large proportion of the Kenyan population indirectly derives its livelihood from the dairy industry (KDB, 2009). The main produce of the dairy sector is the milk. Neumann *et al*., (2002) and Njarui *et al*., (2011) highlighted the importance of milk as dietary nutrient. Milk provides high animal protein, micronutrients such iron, zinc, vitamin B-12, riboflavin and conjugated linoleic acids required in the human body. In addition, Neumann *et al*., (2002) reported that milk intake as human food results in improved maternal, fetal and child health i.e successful births, reduced maternal mortality, increased pre-natal growth rates and improved cognitive functions in the body. Further, Njarui *et al*., (2011), reported that processed milk products, like ghee, contain high nutrients concentration (vitamins A, D, E, K and essential fatty acids) than fluid milk.

Dairy industry is also useful for income generation when the milk or live animals are sold by the households. The dairy cattle are sold to reduce the stocking density or for culling purposes due to old age, unproductive animals and prevention of inbreeding. Kabirizi *et al*., (2013) noted that dairy development projects such as Heifer Project International had distributed dairy cows to resource-poor women to help end hunger and poverty. This is attributed to fact that income is generated when excess milk produce is sold to other consumers for domestic consumption or for industrial processing of milk products, such as yoghurt, butter, and ghee. However, it is the quality of milk that is marketable that determines the income generated, domestic consumption or its use as raw material in the agro-based industries.

Dairying is also very important for health reasons. Kabirizi *et al*., (2013) noted that dairying is an important mitigation strategy for HIV/AIDS for the affected families as the high value milk nutrients contributes to better health and productive labour for agricultural production.

Dairying is equally important for integrated crop-livestock systems especially in rural farming. The dairy cattle provide manure which is used to replenish the lost nutrients in the soils of the cultivated farms. This crop-dairying integration is also important in diversification of income of the dairy farmers. This also helps in reducing the cost of feedstuffs and fertilizers and better returns are realized by the dairy farmers.

2.1.4 Milk Demand and Development of Dairy Industry in Kenya

Milk is a very perishable produce. It easily spoils if produced in unhygienic conditions or contaminated during handling. This greatly affects amounts of milk supplied to meet the ever-increasing milk demand. Hygienic production and handling of milk is crucial for continued availability of quality milk and profitable dairying. This calls for embracing of hygienic production and handling practices.

The increase in human population has caused increased demand for quality milk and its related products. In order to continue producing high quality milk to meet the milk demand, development of the dairy industry is paramount. This can be achieved through dissemination and adoption of appropriate dairy and forage technologies by majority of resource-poor small scale farmers (Nicholson *et al*., 2004) in the highlands (where land is scarce and farm sizes are small) and in the ASALs (where land is less productive). Improvement in milk production can also be realized, by increasing government budgetary allocations to the dairy sector (Kavoi *et al*., 2010). In addition, dairy production in the ASALs can be intensified through breeding programmes by introducing dairy cattle with a higher genetic potential for milk production (Nicholson *et al.,* 2004) and adopting modern forage innovations and animal husbandry practices (Kavoi *et al*., 2010).

2.1.5 Marketing, Value–Addition of Milk and Co-operative Concept in Kenya

Milk value chain is the sum total of all activities carried out for milk to increase milk value in the market and it is essential to maintain continued supply of quality milk. According to Cunningham *et al.*, (2009) marketing of milk is an innovative way of availing the milk produce in safe and uncontaminated form to the consumer. Value-addition of the milk, like traditional and industrial processes, can be done to reduce its perishability and prolong its shelf-life.

Kabirizi *et al*., (2013) reported that improved post-milking handling and processing of milk is essential to ensure high-quality milk and milk products to reach the markets. Losses of fresh milk occur if no value addition is done through preservation and processing. The dairy farmers could generate income and improve household nutrition and food security through milk value addition and efficient marketing. The milk value addition involves processing of raw milk to produce of milk products: ghee, cheese and yoghurt, which fetches better prices and lasts longer than the perishable raw milk. Efficient marketing and value addition methods are also necessary to prolong the use of milk and to keep the quality as milk spoilage is minimized. Besides, it reduces competition along the value chain due to specialization of the different actors.

Hazell *et al*., (2007) examined the future of small farms for poverty reduction in USA. The study revealed that dominant small scale dairy farmers are the most disadvantaged in milk marketing and value-addition. This is because they are still inadequately equipped to compete with resource-rich large commercial farmers. McDermott *et al.*, (2010) examined sustainable intensification of smallholder livestock systems in the tropics. This study revealed that marketing of milk and some value–addition techniques may be expensive to the resource-poor smallholder dairy farmers. This, coupled with lack of or limited equipment and skills, remains a great impediment in production and processing of milk by smallholder dairy farmers.

In order to solve the marketing and milk value-addition inadequacies of the smallholder dairying, there is need to embrace the co-operative concept by the small scale dairy farmers (RoK, 2007). The co-operative movement is normally aimed at helping the small scale farmers to get their market share. This concept, if founded on strong farmer associations and value-adding cooperatives, is bound to be successful in revolutionizing the dairy industry. This is attributed to the fact that co-operatives remain a major channel for collecting milk destined to the formal markets and ensures quality milk is supplied to the clients (Karugia, 2012).

Kodhek (2004) conducted a study on revitalizing the dairy industry in Kenya. The author reported that co-operative societies enhance the financial borrowing power of the farmers. This is achieved through pooling financial resources together. The farmers contribute certain amount of money to the co-operative societies and credit is given to the members at affordable rates. Other societal members form the rotating savings-and-credit associations where they contribute money which is given to members on rotational basis. This forms important source of credit to farmers (Nguthi, 2007) who are in a stronger position to confront poverty and vulnerability while taking advantage of new opportunities in the dairy industry.

2.1.6 Constraints and Challenges in the Dairy Industry in Kenya

Like most agricultural production systems, Kenya's dairy sector faces a host of constraints and challenges. There is limited funding for essential support services, such as veterinary services. This is due to the fact that most of these support services have been liberalized by government since 1992. This is likely to result into inadequate access to breeding and veterinary services and reduced performance of the adopted dairy cattle in the semi-arid regions of South Eastern Kenya. This may lead to non-use of better breeding technologies and consequently widespread use of bulls with unknown breeding value (Burke *et al*., 2007).

The small scale holders in Kenya own small farms (Njarui *et al.,* 2011). These small-sized farms (attributed to high human population) limit farmers' capacity to take advantage of economies of scale. In addition, these small scale holders own small herds of 2-3 cows on average (Place *et al*., 2007; Njarui *et al*., 2011), whose milk productivity is low (Place *et al*., 2007). This may be attributed to poor genetic make–up of the dairy cattle, low animal husbandry skills and unreliable sources of improved dairy cattle (Njarui, *et al.,* 2011).This limits the production level of the milk from the individual household.

Milk produced from the smallholders may be of questionable quality. This may be attributed to unhygienic milk handling practices and under–developed 'cool chains' from the farm to the client. Hence, most of the produced milk is bound to be spoilt or condemned as unfit for human consumption (Njarui, *et al.*, 2011). This is likely to affect the quantity of milk that enters into formal and informal market from the different household units.

The small scale farmers also lack adequate finance /credit (KDB, 2009), access to extension services from well-trained staff required to improve their skills (Kinambuga, 2010) and access to adequate quality feedstuffs (Njarui, *et al.,* 2011). All these influence the financing of dairying, access to relevant information and the feeding regime of the dairy cattle respectively.

Diseases, like mastitis, east coast fever, pneumonia and foot and mouth disease, have significant economic implications to the dairy sector. Many of the smallholder dairy farmers often encounter these diseases in their dairy herds. This greatly affects milk productivity, wellbeing of the dairy cattle, quality of the milk and consequently death of the dairy cattle.

This is a major challenge to the dairy farmers as diseases at times remains undetected as the signs or symptoms are not clearly exhibited early after infection. To ensure the dairy cattle remains healthy, the dairy farmers need to use their experiences to monitor the behavior of the cattle to detect the diseases and right measures put in place to prevent transmission of diseases and treat affected cattle.

Low and erratic rainfall makes the semi-arid regions of South Eastern Kenya particularly challenging for farming (Recha *et al.,* 2013). Increase in human population has also contributed to falling farm size and crop yield; and degradation of land and water resources. Recha *et al.,* (2013) further noted that price distortions, ineffective land distribution and unfavourable land tenure also contribute to milk productivity declines.

The productivity and sustainability of these dairy farmers is greatly threatened by climate variability and climate change. Kibirizi *et al*., (2013) observed that climatic limitations affect feed availability, quality of the feeds, animal performance and farm production. ASALs exhibit erratic unpredictable low rainfall (Mbithi *et al*., 1999) and weather conditions (frequent dry spells with occasional flooding). This leads to frequent crop failure and low crop and livestock productivity (Amwata, 2013) as the primary productivity of the ASALs is adversely affected (Tasokwa, 2011; Amwata, 2013). Thornton *et al.,* (2006) and Amwata, (2013) noted that climate variability and change is expected to further exacerbate the variability in rainfall and temperatures in ASALs. Thus ASALs are the most vulnerable areas to climate-related risks with huge impacts on the small scale dairying that aggravate the poverty levels (Amwata, 2013). Poverty and vulnerability to climate variability and change is a great constraint for development of the dairy industry especially in ASALs (DFID, 2008) and a threat to livelihood security of most rural households (Amwata, 2013).

Agricultural production is viewed as insignificant compared to urban commercial plots (Feder *et al*., 1985). This has led to fragmentation and conversion of agricultural land into urban commercial plots; hence, making it a major constraint to dairying (Swanepoel *at el*., 2011). Further, human pressure for land for settlement, labour constraints, like, lack of skilled labour (World Bank, 2008) and ineffective markets and policies (Sere and Steinfield, 1996) are adversely affecting dairying. Thus there is need to push dairy production towards intensification and commercialization.

Furthermore, failure by farmers to adopt appropriate collective approaches has led to inefficient market system leading to substantial losses to farmers (RoK, 2007). For example, dairy cooperatives that previously contributed to development of smallholder milk marketing and provision of inputs and services at low costs have actually lost out due to many factors: competition, inability to adapt to change, poor payouts, poor management and corruption among others. This has greatly affected the collective power of the farmers.

In order to assist the smallholder dairy farmers to adapt to these challenges and become resilient, practical climate smart technologies and innovations have been developed and disseminated to these dairy farmers. However, as noted by Kabirizi *et al*., (2013) only a limited number of the farmers have embraced the climate resilient farming to increase food production. This is highly attributed to poverty and low income and is likely to jeopardize attainment of Millennium Development Goals (MDGs) 1 – eradicating extreme poverty and hunger. However, development of intensified smallholder dairying will address MDG 1 by generating income and meeting the on-going increase in demand for dairy products

2.2 FORAGE TECHNOLOGIES FOR ENHANCING MILK PRODUCTION

The milk production of dairy cattle is influenced by supply of adequate quantity and quality feedstuffs among other factors, like genetics and level of management. However, availability of quality feedstuffs is a challenge in the semi-arid regions of South Eastern Kenya. This is attributed to effects and vulnerability of climate change. The dairy farmers need to be scientifically informed of technologies to reduce effects of climate change and improve the dairy farmers' livelihoods. For example, formulating balanced rations using available forages is critical in developing better feeding and management programme for dairy herds to realize their full genetic potential. This, therefore, if achieved, implies that the dairy cattle give high milk production and attractive returns are realized by the dairy farmers. Furthermore the dairy cows become healthy, maintain body functions and gain recommended daily weight gains.

Kabirizi *et al*., (2013) observed that numerous climate smart agricultural innovations including agro-forestry, forage management and diversification of farming systems are needed to bolster adaptive capacity and hence resilience of the dairy farmers to climate change. Therefore adoption of forage production-enhancing and saving technologies are needed: to reduce feed scarcity; improve the quality of feedstuff and increase milk yield to meet ever-increasing milk demand and attain MDG 1.

2.2.1 Fodder Crops Technology

Maximum milk production is not determined by feeding the dairy cattle a lot; it is by feeding them with quality mixed rations formulated in the right qualities on basis of crude protein, carbohydrate, mineral and vitamins requirements. With feed costs representing the larger proportion of the total cost of production, the correct nutrient requirements are very important for commercial dairying. However, sufficient supply of quality feedstuffs remains a challenge in the semi-arid regions of south eastern Kenya. Ngigi (2005) in a study of smallholder dairying in Eastern Africa revealed that pasture and fodder shortages are common, especially under rain-fed conditions. This result in uneven milk supplies during the year, requiring costly purchased feed supplements to make up feedstuffs shortfalls. Therefore, there is urgent need for strategies to build resilience for the dairy farmers to adapt to climate change and variability. For example, Lusweti *et al*., (2005), on study of ways of coping with feed shortages during the dry season in Kenya, revealed that scarcity of quality feedstuffs in the dry season has led to adoption of fodder crop technique. In addition, Kabirizi *et al*., (2013) observed that adoption of mixed fodder crops results in increased forage yield, feeding days and milk production in the ASALs of Eastern and Central Africa (ECA).

Orodho (2006), who examined the importance of Napier grass in smallholder dairy industry in Kenya, noted that fodder crops technology involves growing high nutritive plants, like grasses, shrubs and trees, to provide fodder feedstuffs to livestock and improve their feedstuff supply. It is important to note that the best feeding regime is one that reduces feed costs and increases the milk production per cow by maximizing the use of high quality forages which are not fibrous or too lush.

2.2.1.1 Fodder Grasses

Orodho (2006) in a study on the importance of Napier grass in smallholder dairy industry in Kenya indicated that Napier grass (*Pennisetum purpureum*) is the most popular fodder crop for dairy farmers in the high and medium potential areas of Kenya. Napier is easy to establish and is a high yielding fodder. Further the author revealed that Napier is very good for silage making and soil conservation as it is a good soil stabilizer. Napier is gaining popularity in the ASALs for intensive forage production in order to alleviate feed scarcity prevalent in these marginal areas. However, as noted by Ouda (2001) and Lanyasunya *et al.*, (2001), Napier is not suitable for direct grazing since stumping results in poor regeneration. Hence, the Napier grass, once ready, should be cut and carried to feed the dairy cattle in confinement or chopped to make silage. In addition, Napier grass does well under *Tumbukiza* method (TM) in the drylands but, as noted by Orodho (2007), it is not a drought tolerant fodder crop.

Orodho (2006) further reported that Napier grass is vulnerable to disease and pest attacks than other fodder grasses. However, new Napier grass varieties such as Kakamega 1, Kakamega II and Kakamega III, have been developed and identified as high yielding and resistant to Napier grass head smut disease (KDB, 2009). Other fodder grasses cultivated to increase forage production includes Rhodes grass, commonly planted in open fields, and *Panicum*, commonly planted under the TM (Orodho, 2007).

2.2.1.2 Fodder Legumes

Orodho (2005) in a study of intensive forage production for smallholder dairying in East Africa categorized fodder legumes as nitrogen-fixing crops grown by farmers for use as animal feedstuffs. The author revealed that legumes are important in alleviating feed scarcity, reducing costs of feedstuffs and improving soil fertility through nitrogen fixation. The fodder legumes are used as protein supplements for dairy cattle as they have high crude protein. They are also used to supplement mineral and vitamins as they are rich in minerals (calcium, phosphorus) and vitamins (A & D). In addition, Kabirizi *et al*., (2013) noted that fodder legumes increase fodder supply for sustaining feed requirement of the animals and crude protein needed for milk production.

Place *et al*., (2007) examined impacts of fodder trees on milk production amongst smallholder farmers in East Africa. The study revealed that the leaves, pods and twigs of leguminous fodder crops, like *Leucaena*, *Calliandra* and *Gliricidia* species have high protein content. These parts of trees are picked, dried and packed in sacks for future use to provide nutrients for maintenance and production of the dairy cattle during the dry season. Kabirizi *et al.,* (2013) observed that homemade feed blocks made from farm waste agro-industrial by-products and fodder tree leaf hay improves milk yields. In addition, the authors noted that fodder trees are deep-rooted and taps water and nutrients deep in the soil profile enabling better fodder yields and providing wood for fuel used for domestic purposes

In another study, Njarui *et al*., (2000) noted that forage legumes are used as supplement feeds for dual purpose goats in semi-arid areas of Kenya. Kabirizi *et al*., (2013) revealed that fodder trees supplement increases daily milk yield of dairy cows. This is attributed to improved rumen fermentation, fibre digestibility and feed intake upon using the fodder tree supplements. Further, the authors observed that intercropping the fodder grasses and legumes was more beneficial as it increased the fodder yields and reduced weeding costs as legumes, like *lablab*, smoothers weeds. However, Pandey *et al*., (2011) in the manual on improved feeding of dairy cattle by smallholder farmers reported that the leguminous fodders are difficult to ensile due to high protein content and low sugar content. In addition, Kabirizi *et al*., (2013) on catalogue of proven and practical climate smart agricultural innovations and technologies noted that adoption of drought tolerant grasses and legumes depended on the availability of planting materials to the dairy farmers.

2.2.1.3 Crop Residues

Crop residues are remains of annual crops of maize, rice, wheat, pigeon peas and beans among others after harvesting. The crop residues are removed from the fields immediately after harvesting to avoid further losses in nutrient content and are stored in waterproof sheds with raised floors to avoid spoilage or at times they are grazed *in situ.* Kabirizi *et al*., (2013) noted that maize stover and other crop residues provides additional feed resource base during the dry season when other feeds are in short supply. However, Kabirizi *et al*., (2013) noted that over 95% of the crop residue is of low nutritive value due to poor management by the farmers.

Lusweti *et al*., (2005) observed that smallholder dairy farmers chop or add molasses to the crop residue feedstuff in order to increase daily feed intake of the animal and offer remedy to the feed scarcity. In addition, the quantity of crop residues available to livestock fluctuates between seasons due to the erratic rainfall as well as its poor distribution.

2.2.2 *Tumbukiza* Technology

Water stress is common in soils in ASALs and can be reduced by adopting *Tumbukiza* Method (TM). *Tumbukiza* is a Kiswahili word which means to put into a hole or pit. Orodho (2007) recommended growing fodder crops in *tumbukiza* pits in low rainfall areas. This is aimed at enhancing soil fertility conservation and moisture retention for improved herbage production to meet the high feed requirement of the dairy cattle.

TM involves digging of pits which are rectangular (60cm by 60cm wide by 60cm) or circular (60cm deep and 60cm in diameter) in shape (Orodho, 2007). The pits are filled with trash and vegetative material, including farmyard manure and topsoil and then high yielding fodder crops, like Napier grass and *Panicum* grass, are grown in the *tumbukiza* pits. Orodho (2007) noted that in order to increase forage production in the dry season, the farmer needs to add adequate water into the planted holes, which is retained in the pits allowing the Napier grass to grow fast and enable its survival through long dry spells. The TM allows better method of watering, longer cycle in the watering regime and ensures success in supporting the dairy production in dry areas

Orodho (2007) reported that Napier grass produces higher herbage and dry matter yields per unit area under TM than the conventional methods. In addition, the Napier grass has longer lifespan (4-5years) and re-grows faster as manure and water are conserved in the pits. This approach ensures enhanced forage production that sustains more dairy cows than where Napier grass is grown conventionally (Orodho, 2007). For instance, the author revealed that one acre of land where TM is adopted can sustain 2-3 dairy cows for a year against one cow and a calf sustained with conventionally grown Napier. TM technique enables dairy farmers to grow fast growing and yielding fodder crops, like Napier grass and other improved pastures on tiny pieces of land. In addition, Muriuki (2003) on study of policy environment in the Kenya dairy sub-sector noted that the increased Napier yields substantially increases milk yields under the TM technology.

However, (Orodho, 2007) revealed that TM technology has high initial cost which may be a major impediment to adoption of the technology by the resource–poor farmers. Orodho (2007) further revealed that most farmers using TM kept dairy cattle which had high feed requirements. Both large and small scale farms practiced zero-grazing for their intensified dairying and most of these farmers used TM to produce supplement feedstuff for their zero-grazed dairy animals.

2.2.3 Feed Conservation Technologies

Kabirizi *et al*., (2013) observed that inadequate year-round fodder supply is a major constraint to the flourishing smallholder dairy industry in ECA. In addition, with feed wastage and contamination (common in ASALs) and effects of population pressure on land and negative impacts of climate change, the problem will worsen in future. This calls for need to adopt feed conservation techniques for feed supply and income generation for households.

Conservation of surplus feed during wet seasons makes it available during the dry season. Feed can be conserved either as hay (dry feed) or silage (wet feed). Feed conservation techniques are measures aimed at conserving high quality fodder for the dairy cattle in safe condition and with minimum loss of nutritive value. Muriuki (2003) revealed that feed conservation helps in bridging the gap between the feed requirement of the animals and the production of the feedstuffs and solving feed supply fluctuations between seasons. In the dry season, feedstuff shortage occurs which affects animal productivity levels and may contribute to overgrazing as the animals feeds on the limited available forages in the pasturelands.

2.2.3.1 Hay Making Technique

Hay is a feed resulting from drying of various green, perishable forages to moisture content of between 15-20% (Lusweti *et al*., 2005). It is a product that can be safely stored without significant change in aroma, flavour and nutritive quality of forage (Orodho, 2006). Hay making is used to conserve the excess forage for future use. Ouda (2001) in a manual on managing dryland resources for feeding and caring of livestock noted that hay making is the most common feed conservation method amongst dairy farmers in Kenya.

Hay can be made from different forages materials; Kikuyu grass (*Pennisetum clandestinum*), Guinea grass (*Panicum maximum),* Buffel grass (*Cenchrus ciliaris), Cynodon* species, Rhodes grass (*Chloris gayana*)*,* Couch grass (*Digitaria decumbens*) and some legumes eg *Leucaena* dried leaves - referred to as leucaena leaf meal*, Dolichos and Caliandra* and *Lucerne*. Kabirizi *et al.,* (2013) observed that the fodder tree hay has well balanced amino acids that are protected from degradation in the rumen. This enhances microbial protein fermentation, digestion and feed efficiency. The fodder should be harvested when it is less moist during sunny days to prevent development of fungi such as Aspargillus, which may aggravate allergies or abortions in cattle (Recha *et al*., 2013). Further, hay making is ideal when fodder crops are harvested at the right stage as the crops have maximum nutrients and green matter. For example, legumes are harvested at the flower initiation stage while grasses should be harvested when about 50% grasses have flowered. Lanyasunya (2001) studied factors limiting optimization of smallholder peri-urban dairy production in Kenya and noted that after flowering and seeding, grasses contain low nutrients. Fodder crops with thin stems and more leaves are better suited for haymaking as they dry faster than those with thick, pity stem and small leaves (Moran, 2005).

However, wet weather conditions are an impediment to hay making. Hence hay making is suitable during the dry spell to allow the fodder to dry without spoiling for 2-3 days in the sun (Lusweti *et al*., 2005). Hay is easily attacked by termites - a common problem in the ASALs. Therefore, hay – baled manually or using motorized baler- should be stored on a raised mice-proof roofed platform, like hay barn, to avoid damage by rodents, termites, rain and sunlight.

2.2.3.2 Silage Making Technique

Silage is a feedstuff produced by controlled fermentation of fresh chopped forages under anaerobic conditions. The fermentation of the silage material prevents fresh fodder from decomposing and allows it to keep its nutrient quality. Silage, which takes about 30 to 40 days to mature before feeding, ensures high milk production and healthy dairy cattle, especially during the dry seasons as it is palatable, laxative, digestible and nutritious. Silage requires less floor capacity for storage than hay.

Silage can be stored in polythene/tube (gauge 1000) silos, plastic tank silos, above ground silos and trench or pit silos (Lusweti *et al*., 2005 and Moran, 2005). The silage pits (which are mostly used to prepare silage for large quantities) should be located at places safe from rodents, away from direct light and with higher elevation or slightly slopping to avoid rain water entering into the silage pits. Plastic tank silos and polythene bags are used for making small quantities of silage. The types of silos are selected according to farmer's preference and feeding circumstances in the dairy production system.

Silage is produced by the activities of naturally-occurring bacteria that convert some of the plant sugars into organic acids that preserve nutritional qualities of the feedstuff (Moran, 2005). The ensiling bacteria are *Lactobacilli,* which feed on water-soluble carbohydrates in the cut forages producing organic acids, mainly lactic acid (Woolford, 1990). These bacteria function in the absence of oxygen. In the presence of oxygen, other types of bacteria break down protein in the cut forages leading to decay (Lusweti *et al*., 2005). In addition, the anaerobic conditions in the silos prevent plant respiration and activities of aerobic spoilage microorganisms such as yeasts and moulds. If silage is stored too dry, or insufficiently packed and covered, infiltration of air allows for microbial activity, which depletes acids, allowing the pH to rise and moulds to grow.

Silage is produced by harvesting a forage crop, like Napier grass, maize, sorghum, pear millet and oats among others at high moisture content (greater than 50%). The moist silage crop is thus preserved as air is excluded in the silage silos. The ideal moisture content is tested by taking a small bundle of the fodder and wringing with two hands and if no moisture comes out, it is ready to ensile. In the rainy seasons, it is advisable to wilt the wet fodder in the sun for sometime in order to obtain good silage. It is worthy to note that the leguminous fodders are difficult to ensile as they are low in sugars and rich in proteins – which reduces fermentation process in silage making.

Good quality silage has a pleasant odour, a typical greenish or greenish brown colour and texture (Lusweti *et al*., 2005 and Orodho, 2006). However, badly fermented silage has offensive taste, strong smell, slimy soft texture and black colour and not suitable for feeding the dairy cattle. In addition, Lusweti *et al*., (2005) noted that it is advisable not to feed silage immediately before or during milking especially when the quality is poor as the milk is tainted by the smell of the silage

Silage making is more technical and requires skills and experience, hence the need to educate the farmers. Muriuki (2003) reported that the maintenance of the anaerobic conditions in the silo is a major challenge to most farmers. If silage is made properly, it will contain nearly all the nutritive values present in the forage that is being conserved. Furthermore, addition of molasses, maize bran or cassava flour will improve the quality of the silage by increasing the energy content and also act as preservative. Other silage additives, like formic acid, lime or urea can also be used to enhance silage fermentation and their nutritional quality but cannot compensate for poor silage making and management (McDonald *et al*., 2007). In addition, Lusweti *et al*., (2005) noted that added molasses provide water-soluble carbohydrate for the *Lactobacilli* and also increases the palatability of the silage.

For successful silage making it is worthy to note that forages cut when dew is trapped in them needs wilting in the field for half a day before using them up for silage making. This is necessary to avoid the trapped water in the forages diluting the lactic acid to a higher level than optimal pH of 3.8 to 4.2 (Lusweti *et al*., 2005) which no micro-organism can survive. The high acidic level preserves the silage. In addition, at the higher pH, the protein splitting bacteria ruin the silage reducing its quality (Lusweti *et al*., 2005).

Moran (2005) and Kabirizi *et al.,* (2013) reported that the adoption rate of silage making is low amongst dairy farmers in ECA. This was attributed to rejection of the silage by livestock due to unfamiliar odour and lack of excess forage for preservation or lack of technical skills required to prepare delicate silage among other factors. However, Moran (2005) revealed that silage is not weather-dependent compared to hay making.

2.2.4 Hay Barn Technology

Hay Barn (HB) is a lowly-raised timber or metallic well-ventilated roofed structure used for storage of forage safely. Moran (2005) noted that HB is suitable for conservation in order to retain the nutritional value of the feed at the highest value possible during storage. Lusweti *et al*., (2005) reported that HB has advantages over the traditional way of storing the forage on branches of trees or stacking in gunny bags or in granaries. The traditional ways exposes the forage to either mycotoxins or damage by rains and termites.

The mycotoxins are toxic substances, which are produced by fungi at pre-harvest, during plant growth and at post-harvest during storage, transport, processing and feeding. Aflatoxins, an example of mycotoxins, are produced by *Aspergillus flavus* fungus. Aflatoxin-producing fungus is found in soil, decaying vegetation, hay, and grain undergoing microbiological deterioration. It invades all types of organic substrates whenever conditions are favorable for its growth. Favorable conditions include high moisture content and high temperature. Aflatoxins present dietary risks to people who consume raw milk or contaminated milk. Aflatoxins may also occur in many animal feed concentrates (cereal grains and fishmeal) and forages (pasture grasses, hay and silage) prone to mycotoxin contamination and mould growth. Control of mould growth and mycotoxin contamination is dependent on the on-farm and storage management of feedstuffs. Hence there is need to embrace the HB technology to control the aflatoxin contamination.

2.2.5 Feed Chopping Technique

Efficient feed utilization innovations, like chopping, are equally important. Chopping technique involves cutting the forage into small pieces, i.e 5cm long. This ensures efficient utilization of feeds during feeding and minimizes wastage (Ouma *et al*., 2007). In Kenya, devices used to chop the feedstuffs include pangas, fixed knife cutters, chaff-cutters and pulverizers. Kabirizi *et al*., (2013) reported that traditionally smallholder dairy farmers chop forages using *pangas*. However, the use of *pangas* is very tedious, time consuming, less efficient (low output and lack of uniformity) and dangerous as the operators often chop off their fingers in the process of chopping. Further, Pandey *et al*., (2011) revealed that use of *pangas* results into poor quality silage. This is attributed to fact the large chopped material allows aerobic conditions in the silo that causes the crude protein and its digestibility to decline. This calls for adoption of efficient chopping and labour saving innovations by the dairy farmers.

A chaff-cutter is useful in chopping the feedstuff material safely and less tediously than the *pangas* and chops the fed forage feedstuffs into smaller pieces. Kabirizi, *et al*., (2013) reported that, for instance, the fixed knife forage choppers reduce the labour burden for women and children in feeding dairy cattle. The authors further reported reduced wastage of forage and incidences of accidents when using the modified fixed forage chopper. Moran (2005) noted that chopping is essential in silage making as it increases compaction due to the finer length of the chopped materials.

Karugia (2012) reported that the pulverizer technology is chopping technology which is increasingly becoming popular among farmers. Pulverizer shred the forage materials, like grass and legume hays, fibrous crop residues such as stovers of maize, sorghum, millet, straws of rice into lengths of a few millimeters faster than the other devices. The only limitations of using pulverizer are its high prices and lack of power supply in most rural areas.

Chopping technique, together with the use of modern feed troughs (devices in which the feedstuffs are put for the dairy cattle to feed from), prevents wastage and contamination of chopped feedstuffs (KDB, 2007).

2.3 ADOPTION OF SELECTED FORAGE INNOVATIONS

Rogers (2003) noted that adoption of an innovation occurs through a distinctive mechanism with several stages which depend on attributes of the innovation and characteristics of the potential adopter.

2.3.1 Diffusion and Mechanism of Adoption of Innovations.

Rogers (2003) defined “innovation" as a new idea, practice or "innovative" technology being adopted to improve production. New ideas are associated with some degree of uncertainty and hence, a lack of predictability on their outcome. For a technology to impact on the economic system, blending into the normal routine of the intended economic system without upsetting the system’s state of affairs is required. An innovation is perceived as new by individual farmer if the innovation has relative advantage over his or her traditional way of production. Baltenweck *et al.,* (2006) noted the importance of adoption of new agricultural technologies and concluded that adoption of innovations is the path towards agricultural development, food security and poverty reduction.

However, despite its importance, adoption of technologies and innovations doesn't occur at once. Rogers (2003) noted that potential adopters of an innovation progresses over time through five stages in the diffusion process: they must learn about the innovation (knowledge stage); they must be persuaded of the value of the innovation (persuasion stage); they decide to adopt it (decision stage); they implement the innovation (implementation stage) and finally, the decision must be reaffirmed or rejected (confirmation stage).

It is useful to note that for the innovation to be adopted it must have good attributes which helps in the diffusion of the innovation. Rogers (2003) observed that for an innovation to be adopted it should be tried out easily and the results can be observed. The innovation should also have a relative advantage over other innovations or the present circumstance or traditional practices. In addition, it should not be overly complex to learn or use and it should fit in or is compatible with the circumstances into which it will be adopted. Innovation adoption is constrained by its complexity, high cost (Mamudu *et al.*, 2012) and the inability to change critical variables within units of production. This implies that individual farmers may not have adequate resources required to innovate fast enough to remain competitive (Powell and Grodal, 2005).

An innovation may be rejected by the potential farmers. Rogers (2003) defines rejection as a decision not to adopt an innovation. It is also necessary to note that rejection is not to be confused from discontinuance. Rogers (2003) defined discontinuance as a rejection that occurs after adoption of the innovation/technology. Therefore, extension agents need to be cautious when disseminating new ideas to the farmers. Traditional practices of the potential adopters of innovations need consideration as they determine to what degree the innovations would disrupt other functioning facets of their daily life. Rogers (2003) further noted that disregarding the traditional customs of the people will lead to conflict within the community. This implies, therefore, that traditional customs (beliefs, traditions, ideologies) are critical to development and success of adopted technology.

Furthermore, such a gradual adoption process is complicated if considerations are made about farmers' forward-looking behavior. A farmer may adopt a new technology to part of the land even if this adoption is not optimal for the current time period believing that experience garnered from current adoption will give him or her valuable information on the new technology to assist him or her in making better future decisions (Rogers, 2003). Forward-looking farmers consider both negative and positive impacts of innovation when making adoption decisions. Upon evaluation, fully adoption or discontinuation may occur.

2.3.2 Extension of Innovations

Orodho (1990) defined extension as 'advisory and other services' that help agricultural producers to make the best possible use of the productive resources at their disposal. Extension services, if functioning effectively and innovation suits the farmers' needs, improve agricultural productivity through providing the farmers with information that helps them to optimize their use of limited resources and minimize costs. However, at times even when technologies are available, smallholder farmers have no access to them (Fleury, 2005).

Extension entails overcoming the uncertainty associated with the new technologies. It therefore comes as no surprise that there are several studies set out to establish what these factors are, and how they can be eliminated (if constraints) or promoted (if enhancers) to achieve technology adoption. Orodho (2007) noted that it is often difficult to clearly understand the causes for either success or failure in the adoption of technology. However, failure in adoption of innovations by farmers may be as a result of an inappropriate technology being imposed on the farmers before the technology has been properly tested and tailored to the need of the farmers. Poor adoption of the agricultural technologies may also result from either the farmers' own socio-economic constraints or from the fault of the extension service - insufficient staff, inadequate trained staff, wrong sociological approach, inadequate use of media or the issuing of wrong advice to farmers and lack of transport facilities.

2.3.3 Channels of Extension Services

In Kenya, new technologies may be disseminated through several agencies. This includes research institutions (local or international) like KALRO and universities - which develops innovations through on-farm or on-station research. Private commercial companies, like agro-chemicals and seed companies uses extension as a marketing strategy or co-finances agricultural shows to promote their products. In addition, private non-commercial organizations, whether local and international, like Non-Governmental Organizations (NGOs) and international development agencies such as world vision, Danish International Development Agency (DANIDA), Department for International Development (DFID), USAID and International Fund for Agricultural Development (IFAD) uses their personnel to disseminate new information to the farmers especially for livelihood supporting agricultural activities. Further, the government extension services, like National Agriculture and Livestock Extension Programmes (NALEP) plays an important role through which the farmers receive extension services from government officers on the new innovations (KDB, 2009).

Orodho (1990) reported that the extension agencies use methods that include field-days, demonstrations, fodder bulking sites, visits to research centres, correspondences with farmers, public media, lectures, seminars, scientific papers, farmers' publications and agricultural shows. The author further noted that some of these methods of dissemination have weaknesses for they are dependent on the initiative and willingness of the individual potential adopters. However, Kabirizi *et al*., (2013) noted that the most important sources of information on dairying in these ASALs are farmer-to-farmer contact and electronic media.

In addition, the most successful extension providers involve local communities in problem identification and feasible solution search. The extension workers facilitate the communities to discuss their problems and identify feasible solutions using suitable methods such as Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis. Others extension officers use the integrated approach, which is multifaceted, in order to address other issues that may be affecting the farmers' agricultural productivity (FAO, 2006).

2.4 DETERMINANTS OF ADOPTION OF INNOVATIONS

Gender of the farmer positively or negatively influences adoption of innovations. Doss and Morris (2001) and Kinambuga (2010) suggested that male headed households are more likely to adopt new innovations than female-headed households. This is likely so because in the traditional set-ups, male heads of households own property and are better in accessing the resources needed to use improved technologies for themselves and for their wives. In addition, the males are likely to control resources in the households and influence farm business decisions-making.

Age of farmer is crucial in determining adoption. This is because the number of years the farmer has lived may be a reflection of the experience, wealth status, energy level, attitude, mental outlook and general social interaction. Mamudu *et al.,* (2012) revealed that young people are more flexible in deciding making than older people and may hence adopt improved technologies more than older counterparts. Besides, older farmers have accumulated years of experience in farming through experimentation and observations and may find it difficult to leave such experiences for new technologies. However, Mamudu *et al.,* (2012) also suggested that younger farmers may not be able to adopt modern agricultural production technologies, especially capital intensive ones as they might not have adequate resources to do so.

Education of the farmer has crucial influence on adoption of new innovations. Literacy level (indicated by number of years of the farmers spent on formal schooling) is expected to improve their likelihood of adoption of the innovations. Improved forage technology utilization involves technical applicability. Kinambuga (2010) noted that education increase the understanding of the technology and improve the decision making process and thereby influence the anticipated level and/or composition of other inputs to increase adoption. The literate farmers are able to respond to improved technologies and innovations that enhance better returns from their farm investments. This is associated to the revelation by Doss and Morris (2001) and Kinambuga (2010) that literate farmers easily understand concepts and principles of innovations taught and hence, they are more innovative. Further, studies of Waller *et al.,* (1998) and Caswell *et al.,* (2001) also noted that education creates a favourable mental attitude for the acceptance of new practices in agriculture. In contrast, illiterate farmers are less likely to adopt innovation because of unfavourable mental attitude towards new innovations and poor understanding of theories.

Off-farm income of the household head is a crucial determinant of the kind of innovations adopted and level of intensification of the innovations. Non-farm activities ensure that the farmers have a continuous flow of off-farm income that enables them to afford new technologies. Nguthi (2007) studied adoption of agricultural innovations by smallholder farmers in Kiambu and revealed that continuous flow of off-farm income influences adoption of improved innovations positively. In addition, studies by Kinambuga (2010) and Mamudu *et al.,* (2012) showed that stable income increase the probability of adopting improved agricultural technologies in dairying and forage production.

Family size determines availability of labour for most of the rural households. Nyariki (2011) in a study on examined farm size, modern technology adoption and efficiency of smallholdings in Kenya revealed that small family size is likely to limit family labour available for the intensive agricultural production. This may force many small sized households to engage employee (s) on temporarily or permanent basis. However, Nyariki (2011) concluded that wage-labour is expensive. This is likely to be a major impediment in adoption of labour-intensive forage innovations by the farmers. In addition, farmers with large family size might significantly adopt the technology, to satisfy the needs of their family (Wodajo, 2011). This is attributed to the availability of family labour.

Farm size determines the scale and intensity of operations in the farms. Mamudu *et al*., (2012) revealed that increased human population, urbanization and sub-division of agricultural lands as agriculture is considered less profitable resulted to down-scaling of farm size and intensification of farm operations in Ghana. Wambugu *et al*., (2003) in a study of adoption and dissemination of fodder shrubs in Central Kenya found out that farm sizes were smaller in peri-urban areas. This necessitates intensification of farm operations and adoption of production-enhancing technologies. Place *et al.,* (2009) in a study on the impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa found out that the farm size will continue to shrink and is likely to affect the man-hours of family members or employed personnel and the probability of adoption of dairy and forage innovations by smallholders

Land tenure system influences the security of ownership of land. Secure land ownership, like individual tenure system, is likely to motivate farmers invest in their land by adopting forage innovations to better milk production. In cases of land ownership like family/ancestral or communal tenure systems the dairy farmers feel insecure. This is likely to limit level of investment and probability of adoption of agricultural innovations as the farmers feel insecure.

Years of experience in dairying are also crucial in influencing adoption of agricultural innovations. Mukokha *et al.,* (2007) in a study on analysis of factors influencing adoption of dairy technologies in Western Kenya revealed that households with wealth of experience in dairying are able to have better control of the risks in dairying by diagnosing and controlling diseases and management of dairy cattle. Further, experience improves decision making and resource allocation as a result of improved learning curve of the dairy farmer (Kinambuga, 2010).

Intensification of dairying, through increasing number of dairy cattle kept, is also a crucial factor. To counter-balance the effects of declining farm sizes and meet the increased milk demand, the dairy farmers can intensify their dairy production. Wakhungu *et al.,* (2007) on study of determinants of smallholder dairy farmers' adoption in Kenyan highlands revealed that farmers are coping with intensification by investing heavily in land for improved pasture production, use quality animal feeds and labour-saving technologies. Improved animal husbandry practices are also essential for sustainability of high milk production. For example, Howley *et al.*, (2012) revealed that AI is essential for increased milk production and control of breeding diseases. Further, it is economical for breeding purposes as few or no bulls are kept by the dairy farmers.

Type of feeding management used by the dairy farmer influences the adoption of forage innovations. Sedentary system of feeding of the dairy cattle calls for use of high quality feedstuffs as the animals have limited freedom of selecting of forage due to confinement. These feedstuffs are utilized efficiently with minimal wastage and contamination. This system impacts positively on the adoption of the fodder crops and forage utilization-enhancing technologies, like chopping of feedstuffs and hay making.

Access to credit is expected to influence the probability of adoption of innovations. Farmers with better access to credit are more likely to adopt technologies compared to those with limited access. However, high interest rates and high risks associated with defaulting of borrowed credit discourage dairy farmers from obtaining credit from financial institutions. Lack of initial capital hinders dairy farmers from adopting capital-intensive technologies;

particularly the resource-poor dairy farmers (Wodajo, 2011). Mamudu *et al*., (2012) also revealed that high poverty levels among farmers and lack of access to credit make it difficult for them to afford technologies. This is particularly so given that some modern dairy and forage technologies may be expensive.

Extension service is critical in promoting adoption of innovations in agriculture. Access to information is a constraint for smallholder dairy farmers and uncertainty exists regarding the reliability of innovations (SDP, 2007). However, access to extension services creates platform for acquisition of the relevant information and reduces the uncertainty about a technology's performance. This awareness of the technology changes individual's assessment of the innovation from purely subjective to objective over time, thereby facilitating adoption. Mamudu *et al.,* (2012) revealed that the dairy farmers with access to extension are bound to counter-balance the negative effects of lack of formal education, acquire relevant information or reduce uncertainties about some innovations and then adopt the innovations. Poor access to extension services limits adoption of innovations due to uncertainties or lack of information on operationalization of the ideas.

Expected milk output is an enticing factor in dairy farming. Studies show that farmers' decision to adopt or not to adopt is usually based on the expected yield and risk associated with the new technology. If farmers expect the milk yield from adopting an innovation to be higher than their current methods of farming, they are more likely to adopt it and it is easier to convince the farmers to adopt the technology. Mamudu *et al*., (2012) observed that the expected benefit to be derived from adopting a given technology was positively related to the probability of adoption.

Membership to a co-operative society is also influential in determining adoption of a technology. Wakhungu *et al*., (2007) also noted that the co-operative concept allows dairy farmers to benefit from farm inputs, credit or market of the milk produce. Therefore, dairy farmers who are organized in co-operative society have an advantage over the other non-grouped farmers.

2.5 THEORETICAL FRAMEWORK

The study adopted the Rogers (2003) Innovation-Adoption model as summarized in the Figure 2.1. The framework focused on the stages farmers follow when deciding whether to adopt an innovation, reject the innovation or discontinue the adopted innovation. The theoretical framework shows that a farmer adopts an innovation progressively over time upon which the farmer may wholly adopt it or totally reject it if the innovation is perceived to have no relative advantage over the traditional way of doing farming. In addition, framework shows that an adopted innovation may be discontinued later on by the dairy farmers.

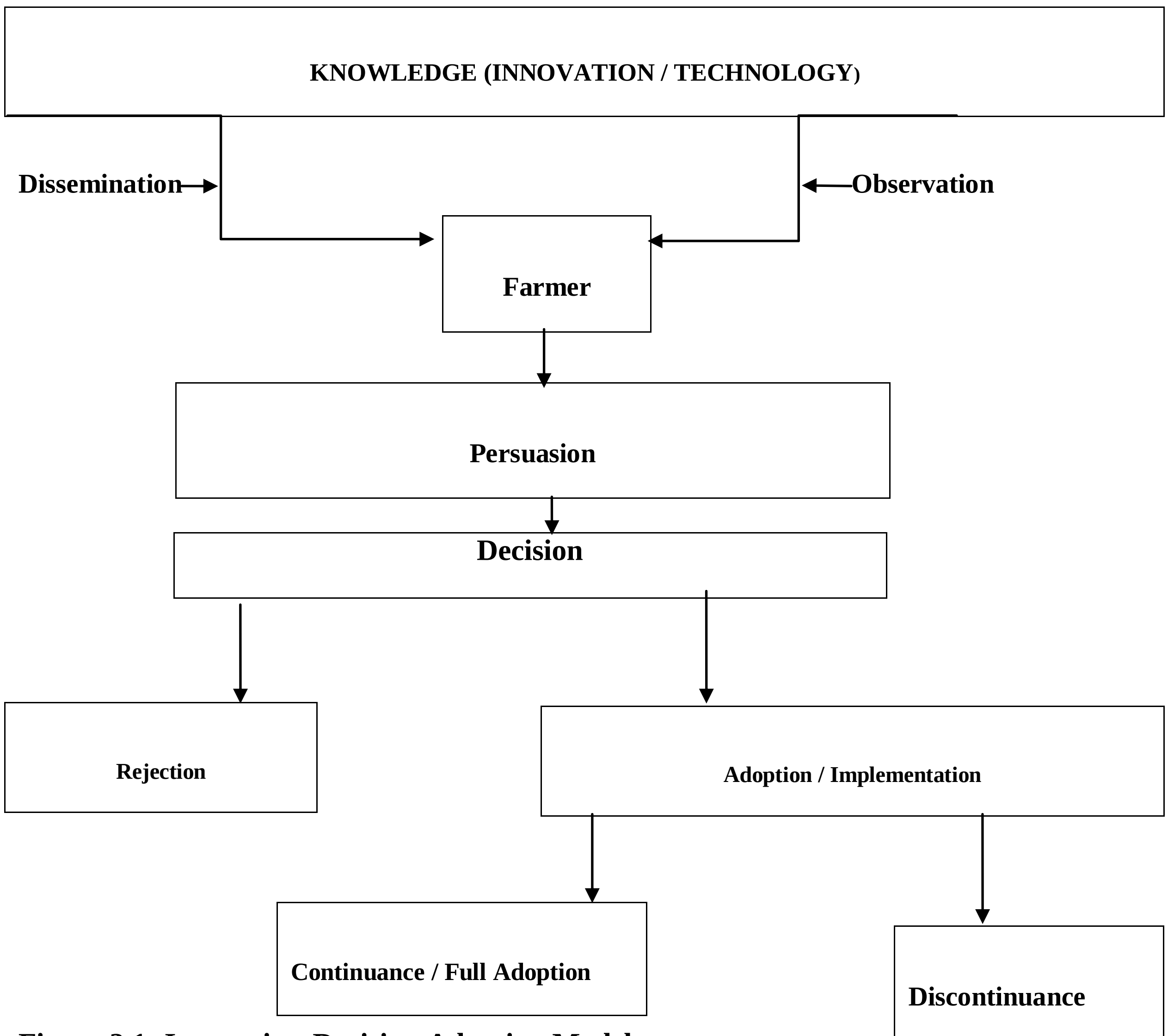

Figure 2.1: Innovation-Decision Adoption Model

Source: Model adopted from Rodgers (2003)

The Innovation-Decision theoretical framework is supported by the Lewin (1951) theory 3-phase model (Figure 2.2) based on principles of unfreezing and freezing of ideas.

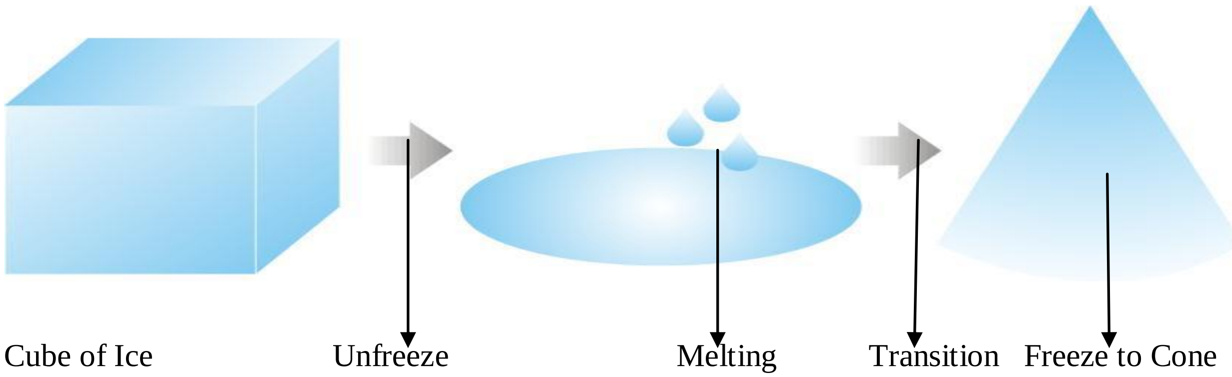

Figure 2.2: Unfreezing-Freezing Model Adopted from Lewin Theory (1951)

According to Lewin (1951) , the unfreezing phase involves reducing the restraining forces that are striving to maintain the status quo and dismantling the current mind set of the individual. This is helpful in highlighting the gaps between the current state of production and the desired benefits. This phase aims at showing that the existing state of affairs or way of production needs to be broken down before the new way of operation is implemented. If not broken, the innovation is rejected and adoption of the innovation fails.

The transition phase involves developing new behaviours, values and attitudes for the innovations. This is achieved through organizational and process changes being adopted by the individual. Lewin (1951) observed that a state of confusion may occur when the individual is moving from the old ways of doing things to the new ways. This may take long or short time as some individuals take time to feel comfortable with an innovation and start acting in ways that are supporting the change initiative.

The freezing phase is the final stage that involves crystallizing and adopting the innovation by the individual. The individual realizes the relative advantage of the innovation and fully implements the innovation. Lewin (1951) suggested that there is need to reinforce the adoption of the innovation through further freezing as the individual may discontinue the adoption of innovation and revert to the old ways of doing things.

The Lewin (1951) model can be likened to change of physical states of water mass on change of the temperature. Lewin (1951) argued that if somebody has a cube of ice, but realizes that a cone of ice is needed, then the cube of ice is firstly melted to make it amenable to the change (unfreeze)**,** mould (change) it into the shape of the cone and then solidify it (freeze) again.

The Rogers' mechanism of diffusion and Kurt-Lewin theory are further supported by the perceived attributes theory. According to Rogers (2003), this theory highlights that there are five attributes of an innovation upon which it is judged: that it can be tried out **(**trialability**),** that results can be observed **(**observability**)**, that it has an advantage over other innovations or the present circumstance **(**relative advantage**)**, that it is not overly complex to learn or use **(**complexity) and that it is compatible with the circumstances into which it will be adopted **(**compatibility)**.**

An innovation, which is relatively simple to understand, is expected to diffuse quickly. Diffusion of an innovation, which is too complex to communicate and to apply, is slow. Rogers (2003) noted that the complexity of an innovation, as perceived by the farmers, is negatively related to its rate and speed of adoption. Thus the above theories were found helpful in explaining the adoption of the production-enhancing and forage technologies in peri-urban dairy production in the two study sites.

2.6 CONCEPTUAL FRAMEWORK

Dairy farmers have different household characteristics which include farmers' education, gender, age, family size and experience in the dairy business, herd size and feeding systems (Kinambuga, 2010). Further, the author noted that the level and kind of other innovations adopted and utilized by a farmer influences the performance of the peri-urban dairying. Similarly, financial, institutional and management factors interact with each other and together they influence the profitability of the farmers in adopting the innovations. In addition, the adoption of selected forage innovations is likely to be influenced by modifying variables - shocks, like, chronic illness, death, land disputes or occurrence of natural hazards – which may affect discharging of duties by the family members or the employee(s). They may also affect the planning and management of the farm operations by the farmer

The adoption of selected forage innovations in the peri-urban dairy production system was the dependent variable in this study. Adoption of forage innovations is likely to be greatly influenced by the demographic characteristics (gender, age, education, and family size), farm (land size, land tenure system) and socio-economic factors (occupation, access to credit and extension, expected milk yield, membership to co-operative movement) of the peri-urban dairy farmers. There were indicators of levels of adoption of the innovations the peri- urban dairy production. They include kind of cattle kept, kind of breeding services, use of *tumbukiza* pits, kind of fodder crops planted, kind of conservation methods, use of hay barns, amount of milk yield obtained per day and membership to marketing and value addition society. These indicators can be positively or negatively influenced by demographic, farm, socio-economic factors and some adopted innovations in the dairy sector.

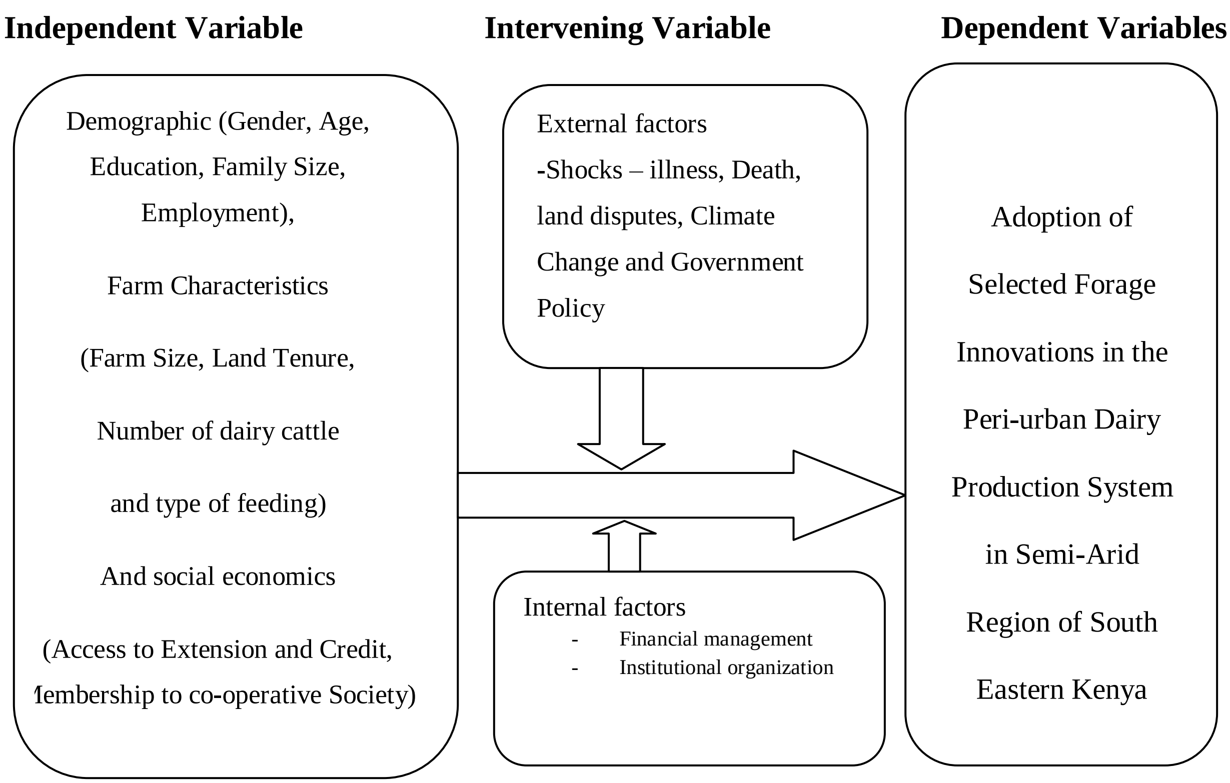

Figure 2.3: Adopted Conceptual Framework

Source: Self

CHAPTER 3

RESEARCH METHODOLOGY

3.0 INTRODUCTION

This chapter contains a description of the study area, the methods and tool used in the collection of data and the sampling frame. A review of techniques used to analyze the kind of data obtained, including their limitations is presented and the conceptual models used for data analysis.

3.1 DESCRIPTION OF STUDY AREA

This study was conducted in two sites, namely, Central Division, Machakos County and Wote Division, Makueni County which represents peri-urban areas found in the semi-arid regions of South Eastern Kenya. In these regions, increase in human population has contributed to falling farm size and crop yield, change in land-use and degradation of land, tree cover and water resources. Ineffective land distribution and unfavourable land tenure also contribute to productivity declines. In order to mitigate on these changes in these two areas, KALRO and ASARECA promoted a project on forage and dairy technologies to peri-urban dairy farmers to enhance dairy performance and make them more resilient. The level of adoption of these technologies and importance to performance is yet to be known. Thus this was the subject of this study.

3.1.1 Machakos County

Central Division represent the peri-urban area of Machakos Town which lies at the coordinates 1º31´S 37º16´E (MoF, 2009). Machakos Town is located 64 kms south east of Nairobi and it is the administrative capital of the Machakos County, Kenya. It is a town whose dominant population is agro-pastoralist Akambas (MoF, 2009), who are engaged in trade and commerce in the town and agricultural activities in the peri-urban environs. In addition, in the recent times, it is rapidly growing due to its proximity to densely populated city of Nairobi.

The Central Division is in agro- ecological zone (AEZ) IV (UM 4) (Jaetzold *et al.*, 2007) and it experiences a semi-arid tropical climate, with a bimodal pattern of rainfall. The long rains fall between March and May, with the peak in April. The rains are very erratic and unreliable at some seasons. They are followed by a dry period that extends to mid-October. The short rains begin in mid-October, peak in November and taper off towards mid-December. Analysis of 47 years (1957-2003) rainfall data at Katumani Weather Station, Central Division shows that the mean annual rainfall is 655 mm (MoF, 2009) but at times mean annual rainfall of 800mm may be realized (Kabirizi *et al*., (2013). The mean maximum temperature is 24.7ºC while the mean minimum temperature is 13.7ºC (MoF, 2009).

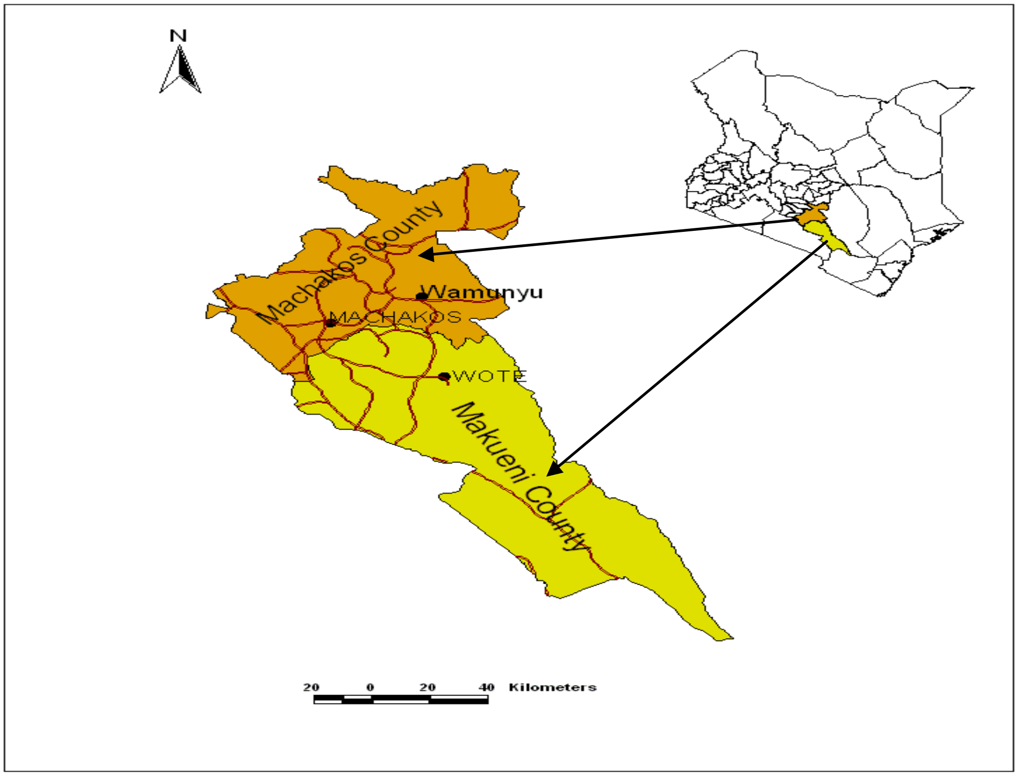

Figure 3.1: Machakos and Makueni Counties in Kenya: Source: Kenya Open Data / MoF/ 2010.

The climatic conditions of Central Division are influenced by altitude (1700m asl) and physical features namely the hilly terrain on the eastern and northern sides. The farmers practice mixed farming where they grow crops and keep animals. The main crops grown in the area are maize, beans, field crops - coffee, citrus fruits and horticultural crops – kales and tomatoes. The main animals kept are dairy cattle, indigenous zebu cattle, sheep, goats and poultry.

The Central Division has a population of 156,377 found in 39,444 households of which 32,676 are farm families whose average farm size is approximately 1.2 ha (MoF, 2009). However, Central Division has an average poverty level of 52 per cent (MoF, 2009).

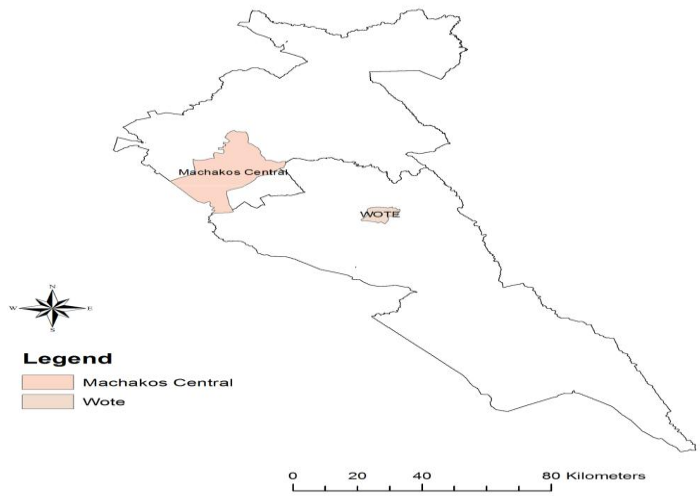

Figure 3.2: Central Division and Wote Division – South Eastern Kenya. Source: GIS/2013

3.1.2 Makueni County

Wote Division represents the peri-urban area of Wote Town, located at co-ordinates 1º47´S 37º38´E, in Makueni County (MoF, 2009). Makueni County is located in the southern end of former Eastern Province and covers an area of 7,965.8 km^2 with a projected population of 1,037,266 and an annual human population growth rate of 2.8% (MoF, 2009). This is exerting high human population pressure on arable and grazing lands. Wote Town is the administrative centre of Makueni County, Kenya with an estimated population of 56,419, of which 5,542 are classified as urban (MoF, 2009).

Wote Division is in AEZ IV (LM 4) (Jaetzold *et al.*, 2007) and experiences a warm tropical semi-arid climate. The rains are bimodal with unreliable long rains received between March-May and more reliable short rains between Mid-October – Mid-December. Wote is drier than Machakos with mean annual rainfall of 550mm. Topography greatly influences the precipitation with the hill masses receiving higher amounts of rainfall. In addition, the rains are generally very erratic, unpredictable and unreliable and crop failure has become common.

Temperature and evaporation rates are generally high with February and September being the hottest months of the year. Minimum mean annual temperatures vary from 14^{o}C to 22^{o}C while maximum mean annual temperatures vary from 26^{o}C to 34^{o}C. At the same time, the occurrence of drought has shown a trend in which the frequency of drought has increased most parts of Kenya. According to Orindi *et al.*, (2006) Kenya used to have regular droughts once every 10 years or so before the 1970s. In the 1970s, drought was experienced once every seven years, in the 1980s they came roughly once every five years, and in the 1990s once every two or three years. According to Amwata (2013), since 2000, four major droughts have been reported in Kenya; 2000, 2004, 2006 and 2009 and nowadays drought occurs almost every year in semi-arid areas in the south eastern Kenya (Recha *et al*., 2013).

The main livelihood activity in the Makueni County is marginal mixed farming. The main crops are maize, beans, cowpeas and pigeon peas and field crops – cotton and citrus fruits while the animals kept are indigenous cattle, dairy cattle in the wetter areas of Kilungu and Mbooni hills (Amwata, 2013), goats, sheep, donkeys and poultry.

3.2 RESEARCH DESIGN, SAMPLING PROCEDURE AND TECHNIQUE

3.2.1 Sampling Techniques

Two stage sampling procedure was used to select the respondents. The first stage involved stratified purposive sampling of farmers engaged by KALRO in the two divisions from the two counties. This was because KALRO and ASARECA, on a collaborative front, were spearheading a project to enhance food security of the farmers and improve their resilience to effects of climate change in Machakos and Makueni counties. The second stage employed simple random sampling to select proportional number of farmers in the locations from each of the two divisions in the respective counties.

3.2.2 Target Population

The target population of study was crop-livestock farmers in the peri-urban environs in the two counties. These farmers were the beneficiaries of KALRO's 'Harnessing crop-livestock integration to enhance food security and livelihoods resilience to effects of climate variability and climate change in Eastern and Central Africa" project funded by ASARECA in Machakos and Makueni Counties since 2010. This target population was carrying out crop-dairy production as a livelihood strategy in the two study areas. The sampling area was for households within locations in a 15 km radius of Machakos Town and Wote Town that constituted peri-urban areas in these semi-arid regions of South Eastern Kenya.

3.2.3 Sample Size

There are different views of determining a sample size. Mugenda *et al.*, (1999) suggested use of a formula if targeted population is greater than 10,860 with similar characteristics of interest. In the current research, the targeted population of the households was less than 10, 860 and therefore a formula could not be applied. Mugenda *et al.*, (1999) further suggested that, if targeted population is less than 10,860, a sample size of n=30 is deemed fit to give reasonable data that can allow statistical analysis.

In addition, Nkonya (1997) argues that there is no first hand rule for obtaining sample size from a targeted population. However, Doss and Morris (2001) cautioned that sample size should be selected in such a way that generalizations can be made about adoption levels for a region or some other aggregate level, such as an administrative district or an agro-ecological zone. Doss and Morris (2001) further suggested that in some instances, it may be useful to oversample some areas to obtain enough data on particular regions or farmer categories in order to obtain statistically significant results about the group.

In line with the view that when n=30 (or greater than) reasonable data can be collected and statistical analysis obtained by Mugenda and Mugenda (1999), a total of 150 farmers were selected to participate in the survey. This included 120 farmers, purposely selected from a list of 300 farmers, who were working with KALRO in ASARECA's funded project in both counties since 2010. This was intended to have a significantly large sample in order to minimize the sampling errors and obtain enough data for statistically reasonable results. The other thirty (30) households were farmers not originally engaged in the project and were included to evaluate whether the technologies had spread to other farmers in the study areas. In addition, the selected households were identified in the northern, eastern, southern and western sides of each of the sampled town. This farmer distribution was aimed at avoiding bias in the data collected in the sampling areas.

3.3 DATA COLLECTION

3.3.1 Types and Sources of Data

The two major types of data are: primary data, which are information gathered directly from the respondent during the research for the purposes of the study; and secondary data, which are information gathered from the published work of other authors, published previous reports, peer review journals, books, and magazines (Wilson, 2010). Primary data were obtained from the respondents who were selected farmers, key informants and opinion leaders while secondary data were sourced from published works in conference proceeding, theses, journals, magazines, government reports, and the internet. Secondary data are important because they act as a support arm of the primary data. They also provide background information on the research topic and serve as a check and standard for evaluating primary data.

3.3.2 Data Collection Tool

Brace (2008) noted that a questionnaire is a schedule of various questions intended for self-completion by survey participants. In addition, the author observed that questionnaire is an effective method for acquiring information especially from a large or sparsely located group of respondents. In line with this view, a semi-structured questionnaire, developed on the basis of the specific objectives of the study, was chosen as the research tool. It had set of questions aimed at gathering information from the respondents without biases or creating psychological sensitivity for the information being sought.

3.3.3 Pre-testing of the Research Tool

Pre-testing of the questionnaire was carried out in the peri-urban environment of Kitui town to ascertain the clarity, suitability and workability of its design. Kitui town was selected because it has similar socio-economic characteristics as those of Machakos and Wote Towns. This was aimed at avoiding disrupting the real data collection in the peri-urban areas of Machakos and Wote Towns because it was likely that the same households may be used in the data collection exercise.

A sample of 8 respondents was used in the pre-testing exercise of the questionnaire as the data was not meant to yield meaningful results on data analysis in the survey. In addition, expert opinion was requested on the representativeness and suitability of questions and gave suggestions of corrections to be made to the structure of the research tool. This helped to improve the content, validity and reliability of the data that would be collected.

3.3.4 Data Collection Procedure

The research work used an ex post facto design. In this design, data collection is done after naturally occurring event, which involves collection of information from a sample that has been drawn from a population that has received a natural treatment not designed by researcher (Fraenkel and Wallen, 2000).

The researcher obtained an introductory letter from the university to collect data from the farmers. Four enumerators were trained on how to use the research tool during the data collection and enough copies of the questionnaire were produced. During the data collection, the respondents were briefed on the purpose of the study and they were assured that the responses would be analysized for academic reasons and kept confidential.

In order to achieve the goals and objectives, research was conducted through the following process:

i). Field surveys using semi-structured detailed questionnaires were done during interview schedules in order to collect primary data on technologies' dissemination, their levels of adoption, challenges and the determinants of the adoption of these forage technologies in peri-urban dairy production system in semi-arid region of south eastern Kenya.

ii). Focus Group Discussions (FGD) were conducted in the study areas to gather complementary data. In addition, key informant interviews (KII) were held with extension agents, input distributors, agro-dealers/agro-vets and development agencies.

iii). Farm visits to observe and assess what was on the ground and the extent of adopted technologies were done.

Data collection was carried out in the study areas between November 2012 and March 2013 in which the respondents were interviewed using the questionnaires. In addition, FGDs and field observations were made to complement the data from the household interviews.

3.4 DATA MANAGEMENT AND ANALYSIS

All the responses in the questionnaire were coded and then all the questionnaires numbered. Using Statistical Package for Social Sciences (SPSS) version 11.5 (SPSS, 2002), the coded information from the questionnaires was fed to the computer and cleaned.

3.4.1 Data Analysis Methods

Walsh and Wigen (2003) noted that the type of tool used for data analysis is dependent on the type of the data; whether qualitative or quantitative. In addition, Wilson, (2010) revealed that frequency tables and statistical software packages can be used to analyze quantitative data. The qualitative data takes an exploratory or conceptual context analysis process which is more ideal as the information gathered from the open ended questions which are large and can be time consuming if not well planned (Wilson, 2010).

3.4.2 Descriptive Statistics

Descriptive statistics provided information on the extent of adoption of the forage technologies. Extent of adoption of the selected forage techniques was obtained and expressed using frequencies and percentage of farmers carrying out each particular technology in the two study areas. A chi-square test was done to determine whether there was statistical difference for each of the innovation adopted in the two sites.

In addition, using descriptive analysis, the constraints limiting extent of adoption of innovations were identified. A comparison of descriptive data from the two sites was made through percentages. Descriptive analysis does often provide guidance for more advanced quantitative analyses. However, the limitation with this analytical procedure was that descriptive statistics do not show the relationship among the variables and the influence that each variable may have on the response.

3.4.3 Crosstabs Chi-Square Tests

Cross tabulations were used to give crosstabs Chi-square tests. Cross tabulations are useful for summarizing categorical variables. The crosstabs chi-square test, is used to measure whether there is some level of association among categorical variable in two-way and multi-way contingency tables. Variables for which the test statistic is significant at a set cut-off point are considered associated, while those for which the test statistic is not significant are not associated. However, the test does not indicate the direction, or even the magnitude of the association, thus it is not sufficient to use this analytical approach alone.

3.4.4 Regression Analysis

Regression analyses were performed to address the inadequacy of descriptive analyses of failing to show the contribution of the factor affecting adoption. Regression statistics tackle the direction and magnitude of each of the variables that influences the dependent variable.

Binary logistic regression method was used to establish the direction of influence and significance level of each variable considered to influence adoption of forage innovation. The logistic model helped to determine the factors that influenced adoption of selected forage and dairy production-enhancing innovations. The regression analysis involved studying the prediction of outcome/dependent variable (adoption of innovation) from a set of several predictor/independent variables.

3.4.5 Description of Analytical Model

The multiple regression model is an analytical model in which the outcome variable (Yi) is predicted from a combination of each predictor variable (Xi) multiplied by its respective regression coefficient (βi).

This multiple regression model can be summarized as:

$$Yi = \beta 0 + \beta 1\ (x1)i + \beta 2\ (x2)i + \beta 3\ (x3)i + \ldots + \beta K\ (xK)i + \varepsilon i \qquad \text{(i)}$$

Where:

Yi = Variable Yi is designated as the “dependent variable.”

$_X1$, $_X2$ …..……, $_XK$ are predictor / explanatory variables used in the model.

β0= Constant value of the model for different variable.

$\beta1$, $\beta2$……. βK are coefficients of the variables, $_X1$, $_X2$ ……, $_XK$ used for each dependent variable in the model.

In this model, the coefficients (β's) are non-random values but of unknown quantities. The noise terms $\varepsilon1$, $\varepsilon2$, $\varepsilon3$, …, εn are random and unobserved and it is further assumed that these ε's are statistically independent, each with mean 0 and (unknown) standard deviation σ (Field, 2006).

Therefore, the fitted multiple regression model was:

$$Yi = \beta0 + \beta1\ (x1)i + \beta2\ (x2)i + \beta3\ (x3)i + \ldots\ldots\ldots\ldots.. + \beta K\ (xK)i \qquad \text{(ii)}$$

In this model;

Yi: Adoption of technology (0=Adopters, 1=Non-adopters)

X_1: Gender of the Household head (0= Male, 1= Female)

X_2: Age of the Household head {0= Mature (>35yrs), 1= Youth (18-35yrs)}

X_3: Education of Household Head {0= Literate (>Post-Primary), 1 = Illiterate ≤Post-Primary)}

X_4: Formal Employment (0=Yes, 1=No)

X_5: Family size {0= Large (>7 persons), 1= Small (≤7 persons)}

X_6: Farm size {0= Large (>3ha), 1= Small (≤3ha)}

X_7: Land Tenure system (0=Freehold /Secure, 1=Ancestral/Family/Insecure)

X_8: Experience in dairying {0=High (>10yrs), 1= Low (≤10yrs)}

X_9: Number of Dairy cattle kept {0=High (>3 Cows), 1=Low (≤3 Cows)}

X_{10}: Type of Feeding (0=Zero-grazing, 1=No Zero-grazing)

X_{11}: Access to Extension (0=Yes, 1=No)

X_{12}: Access to Credit (0=Yes, 1=No)

X_{13}: Expected milk yield {0=High (>10Litres/Day/Cow), 1=Low (≤10Litres/Day/Cow)}

X_{14}: Membership to a Co-operative (0=Yes, 1=No)

However, the fitted multiple regression model could not be used to predict the extent of adoption of the innovations because the dependent and independent variables were categorical. Therefore, the analytical model had to be adjusted to predict the probability of outcome by adjusting it to binary logistic regression. This is because it is type of multiple regression, with an outcome variable that is a categorical dichotomy but the predictor variables are either categorical or continuous. Binary logistic models are the most popular type because binary data are a common type of categorical data - the response is either a 'success' or a 'failure'. The ordinal logistic regression model is used when the dependent variable is ordered while nominal logistic handles nominal categorical responses. For categorical variables, it is inappropriate to use linear regression because the response values are not measured on a ratio scale and the error terms are not normally distributed (Mamudu *et al*., 2012).

In adopted logistic regression, instead of predicting the value of outcome variable (Yi) from the predictors (Xi), the probability of Yi occurring is predicted from known values of Xi.

$$P(Y) = \frac{1}{1 + e^{-(b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_n x_n + \varepsilon i}} \quad \text{(iii)}$$

Further in dichotomous data, linear relationship between dependent variable (Yi) and independent variables (Xi) doesn't exist. This calls for logit transformation to solve the non-linearity relationship in which the transformation makes the form of the relationship linear while leaving the relationship itself non-linear. This transformation is natural logarithm of the odds that some event will occur and does not estimate parameters using the method of least squares by minimizing the sum of squared deviations of predicted values from observed values. This is because in logistic regression, least squares estimation is not capable of producing minimum variance, unbiased estimators for the actual parameters.

In place of least squares estimation, maximum likelihood estimation (-2LL) is used to solve for the parameters that best fit the data and show the suitability of the model in predicting the outcome. The log-likelihood is analogous to the residual sum of squares in multiple regression and show how information after the model has been fitted

$$Log - Likelihood = \sum_{i=1}^{N} \{YiIn(P(Yi)) + (1 - Yi)In[1 - P(Yi)]\} \quad \text{(iv)}$$

When log-likelihood value is large, it shows that the adopted model is poor in explaining the relationship between the dependent (outcome) and independent variables (predictors). When the log-likelihood (-2LogL= -2LL) value is small, the model is suitable for explaining the relationship (Field, 2006). Thus when the model exactly represents the data, the likelihood is 1 and -2LL statistics is zero. For this reason, the lower -2LL statistic always shows a better model (Field, 2006).

3.4.6 Goodness of Fit of the Adopted Analytical Model

When testing the meaningfulness of model, Chi-square ($\chi 2$) statistic was considered. The $\chi 2$ statistic test in the loβgistic regression model indicates the improvement of the model in predicting the probability of the outcome (Field, 2006). The χ 2 statistic shows the fault only when there is a constant term in the model and then it determines whether all the logistic coefficients except the constant term are equal to zero (Field, 2006). The $\chi 2$ statistic conforms to $\chi 2$ distributions with degree of freedom equals to difference between the parameter number of examined model and parameters of model with constant term.

In this study, the logistic regression was used because it was found to be ideal for the dichotomous outcome variables and categorical predicators (Field, 2006), with some predictors having continuous effects on adoption of the innovations. The logistic regression model was applied for each dependent variable under study in order to evaluate the factors influencing the adoption of the various technologies. Then from the regression tables obtained, significantly influential factors were identified for each technology under study.

Further, the determinants of the likelihood of adoption of innovations were analysized using logistic regression model. The parameter coefficients (β), wald statistic and Exp (β) values for each selected innovation under study were presented in the logistic regression tables from which discussions are done and conclusions drawn thereafter. Parameter estimate (β) represents the change in the logit of the outcome variable associated with one-unit change in the predictor variableis the logit of the natural logarithm of the odds of Y (Outcome) occurring. Wald statistic is important in telling whether the parameter co-efficient for the predictor is significantly different from zero. If it significantly different then the parameter makes a significant contribution to the prediction of adoption of the innovation. Exp (β) shows change in favour of the outcome of the predictor that occurs when predictor changes by unit change.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Demographic Characteristics of the Respondents and Households

On average, about 57.5% of the respondents were males and 42.5% were females (Table 4.1). The class mode of age of the respondents was 36-60 years. There were relatively small responses from the young and old respondents. Thus the responses were unbiased on gender and valid as they were obtained from responsible and rational persons in the areas of study.

Majority (80.0%) of the households were male headed (79.0% in peri-urban area of Machakos Town and 81.0% in peri-urban area of Wote Town). The age of the household head ranged between 21-80 years, with majority of the household heads in Machakos (96.0%) and in Wote (87.5%) aged between 36-60 years of age (Table 4.1) and there was normal distribution of household heads' age. Most of the household heads in Machakos ((96.0%) and in Wote (87.0%) were literate (Table 4.1) which had a significant value at $p<0.05$.

Majority of the household heads in Machakos (80.0%) and Wote (85.0%) had stable off-farm income. In addition, only a small proportion (17.5%) of the farmers was engaged in full-time farming (Table 4.1). Family size ranged between 3 – 9 persons per household with majority (52.0%) of households in peri-urban area of Machakos Town being small (2-3 persons) while majority (58.8%) of households in peri-urban area of Wote Town had medium household sizes (4-7 persons) (Table 4.1), which were significantly different at $p<0.05$. In addition, majority (78%) of the men were not involved in the manual activities but were involved in marketing of milk and purchase of farm inputs. In contrast, majority (81%) of women (and times assisted by children or employees) were involved in the manual activities of the farm, like harvesting of fodder crops, milking of cattle and chopping of feedstuffs.

4.1.2 Farm Characteristics and Production System

Farm size of households ranged from 0.8ha to 20ha and were statistically different at $p<0.05$ in the two peri-urban areas. Majority (79.9%) of farms were small-sized (< 3ha) in peri-urban area of Machakos Town. However, the average farm sizes were larger in peri-urban area of Wote Town with majority (79.0%) having parcels of land that ranged from 4.8ha to 20ha.

Majority (56.7%) of the farmers owned consolidated land units (See Appendix 1). The rest of the farmers (43.3%) had more than one land parcels; of which 28.0% had two parcels, 12.7% had three parcels while less than one percent (< 1%) had more than three parcels. Further, the distance between the land units ranged from ¼ km to more than 3km for the households with average distance between the land units being 2 km.

Significant different forms of land tenure systems existed in both peri-urban areas. On average, most of the farmers (53.1%) had free-hold land tenure system while 35.4% had ancestral land tenure system of ownership (Table 4.1). Some farmers (11.0% on average) had both ancestral and free-hold forms of land ownership. Tenancy form of ownership of land was relative uncommon as the data analysis showed that only 0.05% of the respondents practiced it.

Table 4.1: Demographic & Socio-Economic Characteristics in Peri-urban Semi-arid Regions of South Eastern Kenya

Household Characteristics	**Category**	**Machakos (n=70)**	**Wote (n =80)**	$\chi2$ (P-Value)
Respondents by Gender (%)	Male	60.0	55.0	12.4(.851)
	Female	40.0	45.0	
Gender of Household Head (%)	Male	79.0	81.0	3.56(.022*)
	Female	21.0	19.0	
Age of Household Head (%)	Youthful (18 - 35)	4.0	12.5	32.8(.033*)
	Mature (> 35)	96.0	87.5	
	Average Age (Yrs)	53±2	51±3	
Education of Household Head (%)	Illiterate	4.0	13.0	27.4(.002*)
	Literate	96.0	87.0	
Occupation (%)	Farming	20.0	15.0	27.8(.681)
	Civil Servants	40.0	51.0	
	Business	09.0	14.0	
	Private Sector	20.0	13.0	
	NGOs/ Church	11.0	07.0	
Family Size /No. of Persons (%)	Small (2-3)	52.0	41.2	21.2(.001*)
	Medium (4-7)	47.1	56.4	
	Large (≥8)	0.9	2.4	
	Average Family size (No)	3.1±2.1	4.1± 3.1	
Farm Size in Ha (%)	Small (<3 ha)	79.9	21.0	103.(.002*)
	Large (≥3ha)	20.1	79.0	
	Average Land Size (Ha)	1.2±0.4	7.2±2.4	
Land Tenure System (%)	Free-hold/Secure	35.8	25.0	24.9(.034*)
	Ancestral/Insecure	64.2	75.0	
Access to Credit (%)	Good	60.0	38.0	22.6(.042*)
	Poor	40.0	62.0	
Access to Extension (%)	Good	71.3	39.0	14.2(.001*)
	Poor	28.7	61.0	
Off-Farm Income (%)	Yes	80.0	85.0	12.9(.064)
	No	20.0	15.0	

***Significant at p<0.05**

Table 4.1 shows that access to extension was high (71.3%) in peri-urban area of Machakos Town while only 39.0% of the households in the peri-urban area of Wote Town had access to extension. In addition, most farmers (62.0%) had limited access to credit in peri-urban area of Wote Town while a majority (60.0%) of the households in the peri-urban area of Machakos Town had access to credit. This was bound to affect the likelihood of adoption capital-intensive innovations in peri-urban area of Wote Town.

The farmers in both study sites practiced mixed farming: growing maize, beans, cowpeas and citrus fruits and rearing indigenous cattle, dairy cattle and poultry. However, some farmers were further diversifying their agricultural production with pigs and rabbits rearing.

4.1.4 Characteristics of Peri-urban Dairy production in Machakos and Wote Counties

The descriptive statistics showed that Holstein-Friesian (Fig 4.1), Aryshire, Jersey, Sahiwal breeds were the main breeds kept. Friesian breed was most preferred by the dairy farmers while Sahiwal and CBC were fewer in peri-urban area of Machakos Town compared to those kept in peri-urban area of Wote Town. The Sahiwal and CBC were more adapted to the drier areas of Wote Town and in Machakos Town, the high yielding Friesians were preferred.

Figure 4.1: Holstein-Friesian cow kept by the dairy farmers

On average, farmers owned three dairy cattle (range 1-10) in Machakos Town's peri-urban area while in peri-urban area of Wote Town they owned four dairy cattle (range 1-16) per house-hold (Table 4.2). Lactating cows, heifers and female calves dominated the household herds compared to bulls and male calves.

The households' average milk productivity of the dairy cattle was relatively good. For instance, it was 18.0 Litres/cow/day in Machakos and 16.5 Litres/cow/day in Wote in 2012. The results show a gradual in increase in the average animal milk productivity since 2010 (Table 4.2). The farmers in Machakos and Wote Towns, with 15years and 10 years of experience respectively, were experienced in dairying and were expected to make rational decisions in management of their dairy units.

Table 4.2 shows that milk was sold to farmers' neighbours, milk vendors, catering units, institutions, and co-operative societies. The informal marketing to the neighbours remained the dominant channel in both study sites while the formal marketing to co-operatives or milk processors was found to be uncommon.

Table 4.2: Characteristics of Households' Dairy Production System

Characteristics of Production	**Category**	**Machakos (n=70)**	**Wote (n=80)**	**χ^2(p-value)**
Number of dairy Cattle kept/household		1-10	1-16	11.4(.034*)
Type of Cattle Kept (%)	Friesian	47.0	33.7	23.4(.56)
	Aryshire	22.5	18.8	
	Jersey	17.0	12.9	
	Sahiwal	09.0	14.2	
	Cross-Bred Cattle	4.5	20.4	
Average No. of Cattle Kept per Household		3 ± 2	4 ± 3	
Average Milk Productivity (Lts/Cow/Day)	2010	10.3	8.1	
	2012	18.0	16.5	
Average milk prices (Kshs /Litre)	2010	25	28	
	2012	55	60	
Milk Market Outlets (%)	Neighbours	47	41	32.1(.012*)
	Catering Units	20	29	
	Milk Vendors	23	14	
	Institutions	10	09	
	Co-operatives	-	07	
Experience of Dairying (No.of Years)		15	10	
Adoption of AI (%)	Adopters	21.0	5.7	22.7(.000*)
	Non-Adopters	79.0	94.3	
Availability of AI (%)	Very Good	13.3	8.8	8.4(.075)
	Good	21.3	20.7	
	Fair	3.3	3.3	
	Poor	62.1	67.2	
Success of AI (%)	Very Good	6.7	6.0	7.9(.047*)
	Good	32.0	26.0	
	Fair	1.7	2.0	
	Poor	59.6	66.0	
Charges of AI (%)	1,500/= - 2,000/=	45.3	12.7	25(.000**)
	>2,000/= - 3,000/=	30.0	53.7	
	>3,000/= - 4,000/=	24.7	33.6	
Charges of Repeat AI (%)	Same Charge	81.1	64.8	5.97(.015*)
	Different Charge	18.9	35.2	

Note:*= Significant at p<0.05; ** = Significant at p<0.01; Field Survey/ 2013

Table 4.2 shows that the percentages of farmers using AI technique were relatively low in both peri-urban areas. However, the adoption level of AI was higher (21.0%) in peri-urban area of Machakos Town compared to 5.7% in peri-urban area of Wote Town. This implied that most farmers in both peri-urban areas used breeding bulls (Fig. 4.2) to serve their dairy cows.

Figure 4.2: Holstein-Friesian Breeding Bull used

Availability of AI services varied significantly with most farmers (64.7%) in both peri-urban areas rating it as poor or limited. Charges for the AI services ranged between Ksh 1500/= and 4000/= (Table 4.2). Most farmers (87.3%) in the peri-urban area of Wote Town paid higher charges (> Ksh. 2000/=) for the AI services, while the AI charges were relatively low in the peri-urban area of Machakos Town.

Small proportion of the farmers rated AI service as excellent, 6.7% and 6.0% for the peri-urban areas of Machakos and Wote Towns respectively. A relatively high proportion rated the AI as good (29.0%) in both study sites and large proportion of farmers rated the success of AI services as fair or poor (Table 4.2). This contributed to most of the farmers repeating the AI services. This was a predicament to adoption of AI by the farmers and resulted to the dairy farmers using the bulls for breeding purposes. In addition, embryo transfer technology, although not promoted by KALRO and ASARECA in their collaborative project, was advocated by veterinarians but had not been adopted by the farmers in both study sites.

4.1.4. Descriptive Statistics and Regression Analysis of Innovations' Adoption

Descriptive and regression analyses showed the extent and determinants of adoption of each forage innovation studied in the two study areas in the south eastern Kenya. The results were tabulated in descriptive and regression tables for each forage innovation studied.

4.1.4.1 Adoption Level and Determinants of Adoption of Fodder Crop Technique

Table 4.3 shows that a substantial proportion of the farmers had adopted the fodder crops by 2012 in the peri-urban areas of Machakos (33%) and Wote Towns (38%).

Table 4.3: Adoption of the Fodder Crops by the Farmers (%)

Town	Before 2010	2010	2011	2012	$\chi 2$ (p-value)
Machakos (n=70)	11.0	21.0	31.0	33.0	0.028 (.867)
Wote (n= 80)	09.0	17.0	33.0	38.0	

The adoption of fodder crops by the dairy farmers had an upward trend since 2010 as depicted in the Table 4.3. Moreover, there was significant difference of the adoption of fodder crops between the farmers who were engaged by KALRO and those not engaged by KALRO as depicted in the Table 4.31(Appendix 1).

Further descriptive analysis showed that fodder crops, like Napier (*Pennisetum purperium*), Rhodes (*Chloris gayana*), Guinea (*Panicum maximum*) grasses and; *Dolichos LabLab, Clitoria ternatea* and Leuceana *(Leuceana lecocephala)* legumes found essential for alleviating feed scarcity or used as feed supplements, had been adopted by the dairy farmers as depicted in the Table 4.4.

Table 4.4: Percentage of Respondents Who Adopted Fodder Crops (%)

Town	Napier	Panicum	Rhodes	Lablab	Clitoria	Leuceana	Others
Machakos (n=70)	17.0	2.8	4.2	1.3	1.7	4.2	2.1
Wote (n= 80)	14.0	9.0	3.2	6.4	0.7	3.0	1.7

Napier grass (Fig. 4.3) was the most preferred fodder in both peri-urban areas of Machakos Town (17.0%) and Wote Town (14.0%) and *Clitoria* fodder was the least adopted. The dairy farmers reported that there were limited on-farm multiplication sites of planting materials from the farmers. This was attributed to the fact that the farmers lacked the view that commercial multiplication of these fodder crops would be beneficial and important source of income.

Figure 4.3: Napier grass mostly adopted by dairy farmers on River banks

Panicum and *Lablab* (Fig. 4.4b) were relatively adopted in peri-urban area of Wote Town than in that of Machakos Town. Moreover, *Rhodes* (Fig. 4.4a), *Clitoria* and *Leuceona* had higher adoption percentage in peri-urban area of Machakos than that of Wote Town. However, adoption percentage of legume fodder crops remained relatively low in the two study sites.


a

b

Figure 4.4: ***Rhodes* grass (a) and Dolichos (b) fodders for enhancing feed supply for the dairy cattle**

Descriptive analysis established that dairy farmers had different sources of planting materials for the fodder crops adopted as depicted in the Table 4.5.

Table 4.5: Sources of the Planting Materials (%)

Town	Neighbours	NGOs	MOA	KALRO	Agro-Vets**	χ 2 (p-value)
Machakos (n=23)	47.8	8.8	-	30.4	13.0	6.87 (.018)*
Wote (n= 30)	56.0	4.7	-	21.0	18.3	

Note: *= Significant at p<0.05; ** Sources supplied the seeds for planting only.

Majority of the farmers in peri-urban areas of Machakos (47.8%) and Wote (56.0%) obtained their planting materials from neighbours. KALRO remained the significant single source of planting materials in Machakos (30.4%) and Wote (21.0%). A small percentage of farmers obtained the planting materials from NGOs, Agro-Vets shops (Table 4.5). None of the sampled dairy farmers obtained planting materials from the Ministry of Agriculture, Livestock Development and Fisheries in the semi-arid areas in South Eastern region of Kenya.

A statistical analysis showed that the dairy farmers were faced with different kinds of constraints that affected establishment and adoption of fodder crops planted.

Table 4.6: Constraints for Fodder Establishment (%)

Town	Water Shortage	Lack of skills	Rain Failure	Labour Expenses	χ2 (p-value)
Machakos (n=70)	40.0	27.1	30.0	2.8	5.59 (.139)
Wote (n=80)	22.5	32.5	41.3	3.8	

Water shortage, lack of skills and rainfall failure were reported by the respondents to greatly affect the establishment of the fodder crops in both Wote and Machakos Towns' peri-urban environments (Table 4.6). Small land size and lack of seeds for planting were also reported by some dairy farmers as constraints they facing. However, the statistical differences of the constraints for establishing the fodder crops were not significant at p<0.05 between the two study sites. This implied that the there were no major constraint which had significant contribution to adoption og fodder crop establishment.

Several variables were found to significantly influence adoption of fodder crops as depicted in the Table 4.7.

Table 4.7: Parameter Estimates for Factors affecting Adoption of Fodder Crops

Explanatory Variable	Parameter Estimates (β)	Wald Statistic	Exp (β)	P-Value
Constant	1.124*	27.50	3.069	.001
GenderHH	-1.052*	6.014	.369	.002
AgeHH	1.116	.776	.378	.234
EducationHH	4.561	2.021	.752	.568
EmploymentHH	2.861	3.329	1.321	.876
Family SizeHH	1.121	.747	1.106	.786
Farm SizeHH	-2.546*	.631	2.906	.004
Land Tenure SystemHH	5.611**	7.121	1.722	.001
Experience of DairyingHH	5.257**	16.519	4.711	.002
Number of dairy cattleHH	3.165*	5.27	2.181	.006
Type of FeedingHH	4.124*	12.124	2.739	.003
Access to ExtensionHH	4.133**	10.192	2.395	.004
Access to CreditHH	3.611	1.183	1.571	.001
Expected Milk YieldHH	1.825**	6.924	3.761	.000
Membership to co-opreativeHH	2.467	1.568	1.211	.987

Note: $\chi 2$ = 5.801*; -2LL= 172.79; Overall Statistics= 76.7%; * = Significant at $p<0.05$; ** = Significant at $p<0.01$.

Table 4.7 indicates that the logistic model accounted for 76.7% of the total variation in the adoption of fodder crops. The chi-square statistic ($\chi 2$=5.80) was very strong, indicating that the parameters included in the model were influential in determining the likelihood of adoption of fodder crops. Access to extension services, land tenure system, experience of dairying and expected milk yield were factors that significantly influenced adoption of fodder crops at $p<0.01$. Adoption of fodder crops was positively and significantly influenced by type of feeding and the number of dairy cattle kept at $p<0.05$. However, adoption of fodder crops was negatively influenced by farm size and gender of the household head at $p<0.05$, with the odds in favour of adoption of fodder crops decreased by a factor of 2.906 and 0.369 for farm size and gender of the farmers respectively.

4.1.4.2 Extent and Determinants of Adoption of the Tumbukiza Method

Faced with water shortage and rainfall failure problems the dairy farmers became adaptive and adopted the TM. A statistical descriptive analysis indicated that the dairy farmers had realized the importance of the TM technique as depicted by the relatively high level of adoption in Table 4.8.

Table 4.8: Adoption of Tumbukiza Method (TM) (%)

Town	Tumbukiza	"Fanya Juu/Chini"	Partial Adopters	None	χ 2 (p-value)
Machakos (n=70)	40.0	25.7	5.7	28.6	11.148 (.003)*
Wote (n=80)	48.8	10.7	1.3	39.2	

Note: * = Significant at p<0.05.

A sizeable proportion of the dairy farmers in Machakos (40.0%) and Wote (48.8%) Towns' peri-urban areas had adopted the TM technique (Fig. 4.5). Moreover, there was significant difference of the adoption of TM between the dairy farmers who were engaged by KALRO and those not engaged by KALRO as depicted in the Table 4.31(Appendix 1). However, a considerable number of the dairy farmers in Machakos (25.7%) and Wote Towns (10.7%) were still growing the fodder crops, especially Napier grass, using the soil and water conservation methods, like *Fanya juu* terraces. Further, statistical analysis revealed that a few dairy farmers in Machakos (5.7%) and Wote (1.3%) Towns were using a combination of the TM and conventional techniques.

Figure 4.5: Tumbukiza pits prepared for planting Napier grass in Wote

Regression analysis of the determinants of the adoption of the TM showed that several variables significantly influenced adoption of TM at 95% as depicted in Table 4.9.

Table 4.9: Parameter Estimates for Factors affecting Adoption of TM

Explanatory Variable	Parameter Estimate (β)	Wald Statistic	Exp (β)	P-Value
Constant	.818*	20.909	2.267	.035
GenderHH	-.282	.184	.754	.781
AgeHH	-.233	.130	.793	.652
EducationHH	1.396*	1.253	1.673	.004
EmploymentHH	1.125	.836	.468	.424
Family SizeHH	.406*	1.074	1.011	.002
Farm SizeHH	-1.153*	1.045	1.165	.012
Land Tenure SystemHH	1.483**	7.833	1.610	.016
Experience of DairyingHH	1.120*	2.036	1.127	.001
Number of dairy cattleHH	2.230*	3.552	1.794	.026
Type of FeedingHH	1.414**	2.240	1.512	.005
Access to ExtensionHH	1.635*	2.506	2.201	.007
Access to CreditHH	1.932	1.887	.740	.567
Expected Milk YieldHH	1.092*	3.964	1.912	.034
Membership to Co-operativeHH	.265	.200	1.768	.965

Note: $\chi 2$ = 48.34*; -2LL= 125.511; Overall Statistics= 74.7%; * = Significant at p<0.05; **Significant at p<0.01.

Logistic model explained 75.0% of the total variation in the adoption of TM. Land tenure system of the farmer and type of feeding positively influenced adoption of TM at p<0.01, with odds in favour of adoption of TM increasing by factors of 1.610, and 1.512 respectively. This implied that secure land tenure system and dairy farmers using stall–feeding increased the adoption of TM. Farmer’s education, family size, experience of intensified dairying, access to extension and expected milk yield were significant in influencing the likelihood of adoption of TM at p<0.05. Further, farmer’s age, gender and farm size negatively and insignificantly influenced the likelihood of adoption of TM at p<0.05.This implied that the female household heads and large farms decreased adoption of TM but with no significant contribution. Membership to co-operative, access to credit and employment had no influence on adoption of TM.

4.1.4.4 Descriptive Analysis of Feeding Systems Adopted by the Farmers (%)

Statistical analysis showed that the dairy farmers were using different production systems as depicted in the Table 4.10.

Table 4.10: Type of Feeding Systems (%)

Town	Stall-Feeding	Grazing	Stall-Feeding+Grazing	χ 2 (p-value)
Machakos (n=70)	44.3	11.4	44.3	5.43 (.678)
Wote (n=80)	35.0	20.0	45.0	

Sizeable proportions of the farmers at 44.3% and 35.0% in the peri-urban areas of Machakos and Wote Towns respectively had fully adopted the stall-feeding technique. Another sizeable proportion (44.7% on average) of the dairy farmers used a combination of stall-feeding and grazing production systems. These dairy farmers could graze through free-ranging (Fig. 4.6) or tether their dairy cattle in the morning and stall fed the animals in the afternoon or they could stall-feed the dairy cattle in the morning and then graze or tether them in the afternoon. Moreover, grazing alone, either, using free-ranging (8.0% on average) and tethering (8.0%), were lowly practiced in the study sites. However, some dairy cattle kept were in fair body condition (Fig. 4.6).

Figure 4.6: Dairy cattle grazing in open pastures.

Different structures, like zero-grazing units, feeding slabs, feeding (wooden, metallic, cemented or plastic) troughs only, were used in stall-feeding technique by the dairy farmers (Table 4.11). This was aimed at ensuring that feedstuffs were not contaminated.

Table 4.11: Features of Stall-Feeding Structures (%)

Types of Feeding Structures	Machakos (n=70)	Wote (n=80)	$\chi 2$ (p-value)
Feeding Trough	10.0	10.0	2.786 (.438)
Feeding Slab	12.9	11.2	
Feeding Slab +Feeding Trough	4.3	3.8	
Zero-grazing Unit	61.4	55.0	
None	11.4	20.0	

Table 4.11 indicates adoption of the zero-grazing unit technique at 61.4% and 55.0% in the peri-urban areas of Machakos and Wote Towns' respectively. Other structures used were: feeding (recommended or improvised) trough at 10.7%, feeding slab at 12.0% and a combination of feeding trough and feeding slab at 4.1%. Further, small percentage of the dairy farmers in peri-urban areas of Machakos (11.4%) and Wote (20.0%) Towns respectively had not adopted the stall-feeding technique.

Further descriptive analysis indicated that most of the zero-grazing units were incomplete as depicted in the Table 4.12.

Table 4.12: Components of Zero-grazing Units (%)

Components	Machakos (n=43)	Wote (n=44)	$\chi 2$ (p-value)
Milking Parlour +Feed Trough	11.6	22.7	0.311(.578)
M/P + F/T +Water Trough	32.6	34.1	
M/P +F/T + Water Trough+ Calf Pen	41.8	29.5	
Complete Zero-grazing Unit	14.0	13.7	

*Key - M/P – Milking Parlour; F/T – Feeding Trough

Further, an average of 13.8% of the dairy farmers (n=87) had complete zero-grazing units. However, most (86.2%, n=87) of these farmers had zero-grazing units with only the basic components , like milking parlour, water troughs and improvised feed troughs (Fig. 4.7). These incomplete zero-grazing designs probably affected the efficiency of stall-feeding and the performance of dairy cattle.

The improvised feeding troughs, commonly made of folded and firmed iron sheets or half-cut plastic water drums or 'jericans', were the most common among the resource-poor dairy farmers.

Figure 4.7: Improvised Iron Sheet Feeding trough used for Stall-grazing.

Statistical analysis showed that the dairy farmers were facing numerous problems in their zero-grazing units. This was likely to affect the efficiency of stall-feeding adopted by the farmers.

Table 4.13: Problems observed in the Zero-grazing units (%)

Problem	Machakos (n=43)	Wote (n=44)	χ 2 (p-value)
Poor Drainage	39.5	25.0	3.83 (.430)
Inadequate Space	23.3	20.5	
Poor Drainage +Bad Smell	20.9	27.3	
Roof Leakage	4.7	11.3	
*Good Unit	11.6	15.9	

* Percentage of farmers who had Zero-Grazing Units in good condition.

On average poor drainage was the main problem (32.3%), followed by inadequate space in the cubicles (21.9%), roof leakage over the feeding troughs (8.0%), while a combination of poor drainage and bad smell accounted for 24.1%. However, 13.8% of the dairy farmers had their zero-grazing units (Fig. 4.8) in good state with no noticeable problems.

Figure 4.8: Cemented Feed troughs used for Zero-grazing.

A statistical analysis showed that the dairy farmers cleaned their zero-grazing units at varied frequencies which had significant differences at 95%.

Table 4.14: Cleaning Frequency of the Zero-grazing units (%)

Town	Every Day	Every 2 Days	Every Week (7 Days)	χ2 (p-value)
Machakos (n=43)	32.6	39.5	27.9	0.162 (.048)*
Wote (n=44)	38.6	45.5	15.9	

Note: *= Significant at p<0.05.

On average 35.6% of the farmers cleaned up their zero-grazing units every day while 42.5% cleaned up after two days (Table 4.14). Only 21.9% of the farmers took one week to clean up their zero-grazing units.

4.1.5.5.1 Adoption of Chaff-Cutter Chopping Technique

The study revealed that the dairy farmers had appreciated the benefits of chopping technique. This was attributed to the high adoption percentage of the dairy farmers using the chopping technique in Machakos (98.5%) and Wote (72.5%) areas as depicted in the Table 4.15. However, there was no significant difference of the adoption of chopping technology between the dairy farmers who were engaged by KALRO and those not engaged by KALRO as depicted in the Table 4.31 (Appendix 1).

Table 4.15: Adoption of Chopping Technique (%)

Town	Adopters	Non-Adopters	χ 2 (p-value)
Machakos (n=70)	98.5	1.5	0.092 (.761)
Wote (n=80)	72.5	22.5	

Further descriptive analysis showed that the dairy farmers used different equipments for chopping their feedstuffs as depicted in Table 4.16. Several dairy farmers used a combination of the equipments for chopping of their feedstuffs depending on convenience and workability.

Table 4.16: Chopping Equipments used (%)

Equipment	Machakos (n=69)	Wote (n=58)	χ2 (p-value)
Panga	53.6	55.3	16.992 (.005)*
Fixed Knife Cutter	14.5	12.0	
Industrial Chaff-Cutter	24.6	17.2	
Panga +Fixed Knife cutter	5.9	12.0	
Motorized Chaff-Cutter +Panga	1.4	3.5	

*** Significant at p<0.05.**

Panga was the most widely used means for chopping fodder in Machakos (53.6%) and in Wote (55.6%) Towns. However, the dairy farmers reported that it was tedious and time-consuming to chop feedstuffs using the *panga* especially in households with scarcity of labour or those practising intensified dairying. More effective and time-saving equipments, like chaff-cutter (Fig. 4.9) were adopted by few dairy farmers (Table 4.16) in the peri-urban areas of Machakos and Wote Towns in semi-arid regions of South Eastern Kenya.

Figure 4.9: Chaff-cutter for chopping feedstuffs

The dairy farmers reported that they faced several constraints (Table 4.17) that affected the adoption and use of the improved chopping equipments in their farms. These constraints reduced the efficiency and utilization of the feedstuffs in the dairy farms.

Table 4.17: Constraints affecting usage of Improved Chopping Equipments (%)

Constraint	Machakos (n=70)	Wote (n=80)	$\chi2$ (p-value)
Expensive Equipments	53.4	64.4	9.65 (.657)
Lack of Power supply	18.8	26.5	
Expensive labour	15.2	9.1	
Low Awareness	4.5.	8.7	

The expensive equipments was reported as the main impediment in Machakos (53.4%) and in Wote (64.4%), followed by lack of power, expensive labour and low awareness of the improved chaff-cutter. Some farmers faced multiple constraints in their enterprises.

Regression analysis of the determinants of the adoption of the chopping technique revealed that several variables significantly influenced adoption of chopping technique at 95% as depicted in Table 4.18.

Table 4.18:Parameter Estimates for Factors affecting Adoption of Chopping Technology

Explanatory Variable	Parameter Estimates(β)	Wald Statistic	Exp (β)	P-Value
Constant	43.78*	3.956	2.712	.004
GenderHH	1.400	1.101	1.247	.456
AgeHH	5.865*	2.716	2.213	.002
EducationHH	4.616*	3.122	2.411	.001
EmploymentHH	2.951	1.322	3.422	.742
Family SizeHH	-3.801*	4.561	4.473	.005
Farm SizeHH	-8.777*	6.153	64.67	.001
Land Tenure SystemHH	.073	1.013	1.075	.623
Experience of DairyingHH	5.465**	1.065	84.101	.000
Number of Dairy CattleHH	2.349*	3.466	5.261	.021
Type of FeedingHH	1.354*	2.892	3.873	.012
Access to ExtensionHH	3.721	3.174	2.561	.932
Access to Credit HH	4.106*	5.245	1.832	.003
Expected Milk YieldHH	1.680*	6.141	1.467	.006
Membership to Co-operativeHH	1.328	5.162	1.902	.884

Note: $\chi2$ = 46.72*; -2LL= 70.122;Overall Statistics= 94.34%; * = Significant at p<0.05; **Significant at p<0.01.

The logistic model was good as it explained 94% of the total variation in the adoption of chopping technique. Years of experience in dairying was the most significant and positively influenced the likelihood of adopting feedstuff chopping at $p<0.01$ (Table 4.18). In addition, access to credit positively and significantly influenced adoption of feed choppers at $p<0.01$. Farmers' age, education, number of dairy cattle, type of feeding and expected milk yield significantly and positively influenced the likelihood of feedstuff chopping at $p<0.05$. Further, gender, employment of farmer and membership to a co-operative were non-significant in influencing the likelihood of feedstuff chopping at $p<0.05$. However, family and farm sizes negatively and significantly influenced adoption of feedstuff chopping at $p<0.05$.

4.1.5.6 Adoption Level and Determinants of Adoption of Silage making

The dairy farmers reported that they desired to improve milk productivity of their dairy cows by improving the feeding regimes. This was done by adopting feed conservation measures that produced high quality feedstuffs, like silage making. However, the results showed that silage making was adopted by few dairy farmers in Machakos (10.7%) and Wote (13.7%) as depicted in the Table 4.19. Moreover, there was significant difference of the adoption of silage making between the dairy farmers under KALRO project and those outside the project as depicted in the Table 4.31(Appendix 1).

Table 4.19: Adoption of Silage making (%)

Category	Machakos (n=70)	Wote (n=80)	$\chi2$ (p-value)
Adopters	10.7	13.3	5.32 (.466)
Non-Adopters	89.3	86.7	

Further descriptive statistics showed that the dairy farmers in Machakos (10.7%) and Wote (13.3%) were using mainly polythene tube technique (Table 4.20) for making the technical and quality silage.

Table 4.20: Type of Silos (%)

Type of Silo	Machakos (n=70)	Wote (n=80)	$\chi2$ (p-value)
Polythene Bags	10.7	13.7	2.78 (.124)
Trench silos	0.00	0.00	

The silage making is very technical and challenging and dairy farmers faced varied problems with no significant differences at 95% as depicted in Table 4.21.

Table 4.21: Common Problems in Silage Making (%).

Constraint	**Machakos(n=7)**	**Wote (n=11)**	**$\chi2$ (p-value)**
Moulds Formation	51.5	45.5	10.04 (.234)
Termite Damage	28.5	36.3	
Rain Damage	20.0	18.2	

Note: *=Significant at p<0.05.

The dairy farmers and key informants reported that adoption of the silage making had gradually increased over the years amongst the dairy farmers in Wote Division. However, it was mainly affected by moulds formation (48.5%), termite attack (32.4%) and rain damage (19.1%) in the two study areas (Table 4.21).

Moreover, regression analysis revealed that several variables significantly influenced adoption of silage making at 95% as depicted in Table 4.22.

Table 4.22: Parameter Estimates for Factors affecting Adoption of Silage Technology

Explanatory Variable	**Parameter Estimates(β)**	**Wald Statistic**	**Exp (β)**	**P-Value**
Constant	4.054	.009	57.616	.785
GenderHH	.282	.184	.754	.665
AgeHH	-1.233	1.130	1.793	.432
EducationHH	2.396*	1.252	1.673	.002
EmploymentHH	3.105**	2.201	2.687	.001
Family SizeH	.011	.009	1.011	.586
Farm SizeHH	.153	.045	1.165	.378
Land Tenure SystemHH	1.483*	7.833	1.085	.014
Experience of DairyingHH	1.129**	1.716	4.391	.003
Number of dairy cowsHH	.414	1.240	1.512	.564
Type of FeedingHH	1.214	2.134	1.687	.463
Access to ExtensionHH	1.124**	2.445	1.883	.001
Access to CreditHH	1.932*	1.887	2.540	.003
Expected Milk YieldHH	3.092*	3.964	1.912	.004
Membership to co-operativeHH	.265	.200	.240	.078

Note: $\chi2$ = 43.37*; -2LL= 124.234; Overall Statistics= 77.9%; * = Significant at p<0.05; **Significant at p<0.01.

The logistic model accounted for 78.0% of the total variation in the adoption of silage technology. Farmer's years of experience in dairying, formal employment and access to extension significantly influenced the adoption of silage technology at p<0.01 which increased the odds of adopting silage technology by factor of 4.391, 2.687 and 1.883 respectively. Further, education of the farmer, land tenure system, access to credit and expected milk yield significantly influenced the likelihood of adopting silage technique at $p<0.05$. Contrary to expectation, the odds of adopting silage technology were non-significant for gender and type of feeding. However, age of the farmer was also non-significant and was negatively correlated with the adoption of the silage making at $p<0.05$.

4.1.5.7 Extent and determinants of adoption of hay making techniques

Descriptive analysis indicates that the dairy farmers had realized the importance of making hay. This is attributed to the fact the sizeable proportion of the dairy farmers had adopted hay making and its adoption had an increasing trend since 2010 as depicted in Figure 4.10. Furthermore, there was significant difference of the adoption of hay making between the dairy farmers who were engaged KALRO and those not engaged by KALRO as depicted in the Table 4.31(Appendix 1).

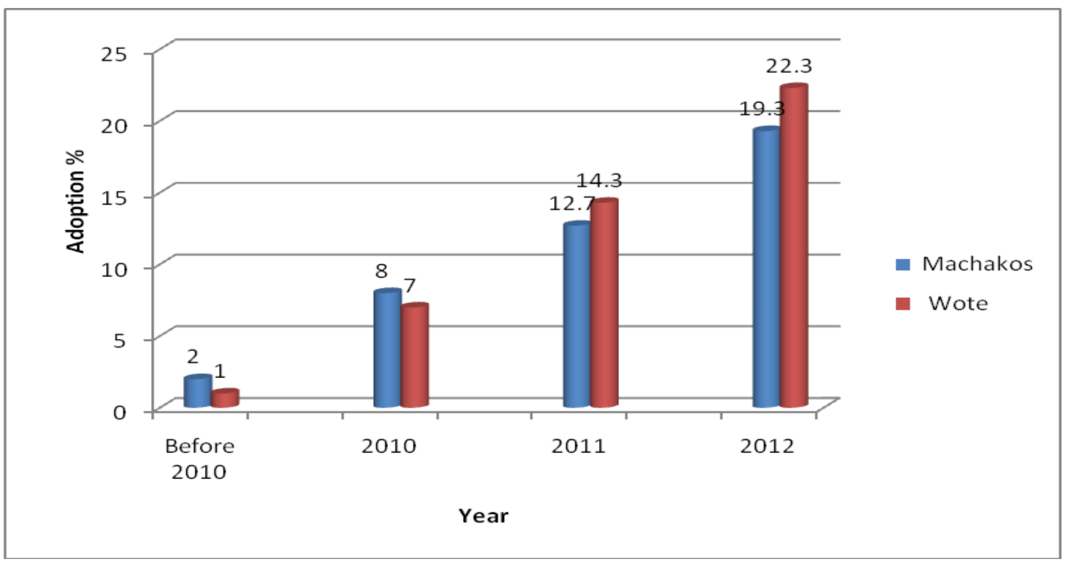

Figure 4.10: Adoption Trend of Hay Making

The adoption of hay making was relatively low in Wote (22.3%) and Machakos (19.3%) in 2012 despite the upward trend in both study sites since 2010. On the other hand, a large proportion of the farmers in Machakos (80.7%) and Wote (77.7%) had not adopted the hay making technique. These dairy farmers would preserve standing hay (Fig. 4.11) in some parts of their farms for use in the dry seasons or in the first three weeks after onset of the rains.

Figure 4.11: Standing Hay

Moreover, the dairy farmers had realized the importance of baling of hay using different equipments to help in stacking of feedstuffs in the hay-barns as depicted in Table 4.23.

Table 4.23: Equipments used for Hay Baling (%)

Town	Hay Box Baling	Mechanized Baling	No Baling	$\chi 2$ (p-value)
Machakos (n=70)	9.3	0.0	10.0	2.35(.623)
Wote (n=80)	13.3	0.3	8.7	

Hay baling using manual hay-box (Fig. 4.12) was most preferred despite its low adoption in Machakos (9.3%) and Wote (13.3%), while the mechanized hay making was only adopted by 0.3% of the dairy farmers in the peri-urban area of Wote Town.

Figure 4.12: Hay Box used for Manual Hay making

Descriptive analysis showed that the practice of hay baling remained relatively low as a sizeable proportion of the dairy farmers were baling the hay made as depicted in the Table 4.24.

Table 4.24: Level of Hay Production (%)

Town	No Baling	No. < 20 Bales	No. >20 Bales	Not Counted
Machakos (n=70)	10.0	4.7	3.3	1.3
Wote (n=80)	8.7	6.0	5.3	2.0

In addition, an average of 9.35% of the farmers was making hay in their farms and stacked it in the HB without baling (Table 4.24).

Hay making was constrained by several factors with no significant differences as depicted in the Table 4.25. These constraints were likely to affect the quality and quantity of hay available for use as feedstuffs.

Table 4.25: Hay Making Constraints (%)

Constraints	Machakos (n=70)	Wote (n=80)	χ 2(p-value)
Inadequate Feedstuffs	16.0	27.3	0.549(.969)
Moulding	2.0	1.3	
Termite Damage	8.7	5.3	
Rodent Menace	6.0	2.7	
Rain Leakage	2.0	1.3	
Moulding + Termite Damage	7.4	10.0	
Expensive Labour + Moulding	4.7	5.3	

Inadequate grass forage was the main constraint (21.7%) the dairy farmers were facing in dairy production. The stored hay was also damaged by termites (14.0%), rodents (8.7%), mould formation (3.3%) and rain leakage (3.3%). Damage due to a combination of mould and termite accounted for 17.4% of the problems affecting the hay storage. Further, regression analysis revealed that the adoption of hay making was significantly influenced by several variables as depicted in the Table 4.26.

Table 4.26: Parameter Estimates for Factors affecting Adoption of Hay Technology

Explanatory Variable	Parameter Estimates(β)	Wald Statistic	Exp (β)	P-Value
Constant	-3.064*	1.211	.047	.002
GenderHH	.800	.0192	.449	.786
AgeHH	.553	.015	1.739	.431
EducationHH	.129	.021	1.137	.912
EmploymentHH	2.441*	1.112	2.301	.001
Family SizeHH	.978	.429	1.658	.786
Farm SizeHH	.348	1.012	1.416	.982
Land Tenure systemHH	.209	.971	1.232	.765
Experience of DairyingHH	1.351*	3.211	1.259	.006
Number of dairy CattleHH	2.363**	1.117	2.351	.001
Type of FeedingHH	1.906	.879	1.783	.866
Access to ExtensionHH	1.012*	1.330	1.415	.003
Access to CreditHH	1.451	1.914	4.267	.541
Expected Milk YieldHH	6.153**	3.718	1.220	.001
Membership to Co-OperativeHH	.678	2.762	1.345	.774

Note: $\chi 2$ = 62.041*; -2LL= 11.09; Overall Statistics= 86.3%; * = Significant at p<0.05; **Significant at p<0.01.

The logistic model accounted for 86.0% of the total variation in the adoption of hay making. The number of dairy cattle kept and expected milk yield significantly at $p<0.01$ and positively influenced the likelihood of adoption of hay making. In addition, education of the household head, years of experience in dairying and access to extension had significant and positive influences on hay making at $p<0.05$. This implies that the more a dairy farmer is educated, with more experience and increased access to extension the more likely he or she will adopt hay making. However, farmer's age, gender, income, family and farm sizes, land tenure system, type of feeding, membership to a co-operative and access to credit were insignificant at $p<0.05$ in influencing the adoption of hay making.

4.1.5.8 Extent and Determinants of Adoption of Hay Barn Technique

Descriptive analysis showed that the dairy farmers had different forms of feedstuffs storage with significant differences as depicted in the Table 4.27.

Table 4.27: Forms of Feedstuffs Storage (%)

Form of Storage	Machakos (n=70)	Wote (n=80)	$\chi 2$ (p-value)
On Trees Top/Branches	4.3	2.5	3.27 (.000)*
Granary	5.7	7.5	
Gunny Bags	7.1	7.4	
Hay Barn	68.6	76.3	
Granary + Gunny Bags	14.3	6.3	

Note: *=Significant at p<0.05.

A large proportion of the farmers had adopted the HB technology (Fig. 4.13) in Machakos (68.6%) and Wote (76.3%). However, there was no significant difference of the adoption of HB technique between the dairy farmers working with KALRO and those not as depicted in the Table 4.31(Appendix 1). It was observed that the hay barns were of variable sizes, different degree of workmanship and improvised protection measures against rains (roofing using plastic sheet or iron sheet) and termites (painting using old engine oil or use of wood ash or use of stone stands to deter termites)

Figure 4.13: Adopted Hay Barn used for storage of feedstuffs

During the study, it was observed that the HB structures were constructed using either timber or metallic posts and roofed using either iron sheets or strong polythene sheets. Other hay barns were poorly constructed and were left uncovered (Fig. 4.14). This was likely to contaminate the feedstuffs with aflatoxin during the rainy season and also reduce feed supply.

Figure 4.14: Uncovered Hay Barn

Some dairy farmers have become creative and adaptive on feed storage. For instance, they stored maize stover ad grass feedstuffs on tree branches (Fig. 4.15a) or on tree-tops and beans and pigeon pea chaffs in gunny bags (Fig. 4.15b) which were stored in granaries for crop residues, like beans chaffs as depicted in the Table 4.27 and Figure 4.15.

 a  b

Figure 4.15: **Improvised forms storage of feedstuffs**

Table 4.28 shows that several variables significantly influenced the adoption of the HB technique.

Table 4.28: Parameter Estimates for Factors affecting Adoption of HB Technology

Explanatory Variable	Parameter Estimates (β)	Wald Statistic	Exp (β)	p-value
Constant	-3.630*	13.239	.027	.006
GenderHH	.528	.172	.357	.984
AgeHH	3.471*	4.829	1.615	.002
EducationHH	.478	.115	.415	.854
EmploymentHH	.724	.243	.393	.563
Family SizeHH	1.012	.034	1.717	.978
Farm SizeHH	1.171	.158	1.207	.675
Land Tenure SystemHH	.978	.685	.722	.724
Experience of DairyingHH	3.465**	6.524	2.026	.000
Number of dairy cattleHH	2.367*	2.790	3.762	.003
Type of FeedingHH	2.817**	3.717	3.107	.001
Access to ExtensionHH	3.418	1.178	3.107	.965
Access to CreditHH	2.372	5.046	1.321	.379
Expected Milk YieldHH	1.435	.515	.898	.786
Membership to Co-operativeHH	.837	2.931	.987	.912

Note: χ^2 = 34.637*; -2LL= 101.33; Overall Statistics =77.8%; * = Significant at $p<0.05$; **Significant at $p<0.01$.

The adopted logistic model was good as it explained 78.0% of the total variation in the adoption of HB technology. Logistic regression analysis showed that type of feeding and experience of dairying significantly ($p<0.01$) influenced adoption of HB. This implies that the more dairy farmers are experienced, who use zero-grazing, the more likely they will adopt HB.

Farmer's age and number of dairy cattle significantly ($p<0.05$) influenced the likelihood of adoption of the HB. This implies that old farmers, with more dairy cows kept were more likely to adopt HB. However, gender, education, employment, family and farm sizes, land tenure system and membership to a co-operative were insignificant ($p<0.05$) factors on adoption of HB.

4.2 DISCUSSION

4.2.1 Demographic Characteristics of the Sampled Households

The dominant male headed households in the two study sites were more likely to adopt new innovations than female headed households. This was attributed to the fact that male headed households are better in accessing the resources needed to use improved technologies for themselves and for their wives. However, in the current research gender remained a non-significant variable for most of the selected forage technologies except fodder crop technique. This implied both male and female-headed households equally adopted the technologies. This was inconsistent with Doss and Morris (2001) and Kinambuga (2010), who revealed that male heads are better adopters of innovations in agriculture. This research finding was in contrast with the view that males were likely to control resources in the households and influence farm business decisions-making due to the view that they have more access to information, extension and credit services than females. For adoption of fodder crops, male influenced its adoption. This was attributed to the fact male exerted authority in establishment of the quality feedstuffs for adopted dairy cattle.

Most dairy farmers in the two study sites were in early fifties. This implied that they had a lot of experience in life, knowledgeable and were bound to make rational decisions in adoption of innovations and change of land-use. This was attributed to the fact that age determines the experience and skills of the households' heads. This is consistent with Doss and Morris (2001), who noted that age determines experience of an adopter of a technology and older farmers use their wealth of experience in making decisions in adopting an innovation. Thus it was expected that older farmers were likely to adopt new innovations, provided the innovation had relative advantage over the conventional way being used. However, for technical innovations, like silage making, age had negative influence on adoption. This implied that the older farmers may have been skeptical in adopting the silage making. This was attributed to fact they could not easily understand the workability of the innovation and reverted to use of simple innovations or the traditional ways of managing the dairy cattle.

Also the youthful farmers in the two study areas were flexible in decision-making and were more likely to adopt the new innovations. This was consistent with Mamudu *et al.,* (2012) who revealed that young people are more flexible in deciding for change than older people and may, hence, adopt improved technologies more than elders. In addition, Mamudu *et al.,* (2012) suggested that younger farmers may not be able to adopt modern agricultural production technologies, especially capital intensive ones as they might not have adequate resources to do so. Besides, older farmers have accumulated years of experience in farming through experimentation and observations and may find it difficult to abandon such experiences for new technologies.

Most dairy farmers had experience in dairying in both study sites. In the current research, experience in dairying was found to significantly influence adoption of most innovations. This concured with Kinambuga, (2010) who concluded that experience helps in decision making and resource allocation as it makes it a better learning curve for the farmer. Mukokha *et al.*, (2007) revealed that dairy farmers use their past experience in dairying to control the risks associated with dairying and they have better control of diseases and management of dairy cattle.

Most farmers were literate and they were expected to improve their likelihood of adoption of the forage innovations. This was attributed to fact that education creates better understanding of technologies. In the current research, it was found out that education significantly influenced adoption of the more technical innovations, like TM, silage making, chopping of feedstuffs. This was in agreement with suggestion by Doss and Morris (2001) and Kinambuga (2010) that literate farmers were more innovative and easily understood concepts and principles of innovations taught. This was also consistent with Waller *et al.,* (1998) and Caswell *et al.*, (2001), who noted that education creates positive attitudes for the acceptance of new practices in agriculture.

Formal employment ensured continuous flow of off-farm income for the dairy farmers to do economic activities. This was expected to influence adoption of forage innovations. However, in the current study, formal employment of the household head was insignificant in influencing adoption of most forage innovations. This was attributed to the fact that most of the forage production-and-utilization enhancing innovations were cheap and affordable to most farmers. This contrasted the findings of Kinambuga (2010) and Mamudu *et al.,* (2012) who found out that stable off-farm income increased the probability of adopting improved agricultural technologies to increase production.

The small (2-3 persons) family sizes, in both study sites, were likely to limit family labour available for the intensive dairying. This was bound to be a major impediment in adoption of labour-intensive innovations as the skilled permanent labour was expensive. Dairy activities were labour intensive and required relatively high labour force and thus households with few family members were not likely to adopt some of the labour-intensive technologies, like TM. This explained why, in the current study, family size significantly influenced labour-intensive innovations, like TM and chopping techniques. For instance, family size negatively influenced chopping technique significantly. This implied that families with many members were unlikely to adopt the chopping technique because they can afford herding labour or cut and carry the forage to feed the confined dairy cattle. This was consistent with Nyariki (2011) in a study on farm size, modern technology adoption and efficiency of small holdings in developing countries noted that small family size limits adoption of labour–intensive technologies. Similarly, the current research noted that family size had no significant influence on adoption of forage innovations that were not labour-intensive, like silage making.

Farm sizes were small (< 3ha) in upper midlands of peri-urban area of Machakos Town. This had an influence on the intensification and adoption of production-enhancing and labour saving technologies. The small (< 3ha) sized farms adopted forage production-enhancing innovations, like TM and forage utilization-enhancing innovations, like chopping in order to increase feedstuff supply and reduce its wastage. This was consistent with findings of Mamudu *et al.,* (2012) and Wambugu *et al.,* (2003) who noted that farm sizes had became smaller, thereby exacerbating feed constraints and leading to land use-change. In peri-urban areas of Wote

Town (located in LM 4), farm sizes were comparatively larger than those in Machakos Town. This was attributed to fact that the human population pressure was low in Wote Town environs. However, the farmers in both areas reported that their farm sizes were decreasing. This agreed with Place *et al.*, (2009) conducted a study of impacts of fodder tree on milk production and income in East Africa noted that farm size continue to shrink and become sub-divided as the population increases. This was likely to affect the man-hours of family members or employed personnel as time is lost when moving from one parcel to another and the probability of adoption of forage innovations by smallholders.

Most farmers, with individual/free-hold land ownership, felt assured of security of land ownership and had high likelihood to adopt land-based innovations to better their investment and production. This contributed greatly to dairy farmers with free-hold land ownership adopting fodder crops and TM for long-term production of quality feedstuffs. However, dairy farmers with ancestral/family land ownership limited their level of investment and probability of adoption of long-term innovations as the farmers were not assured of security of land ownership.

Access to credit increased the probability of adoption of innovations as farmers readily obtained capital for investment. Dairy farmers in peri-urban areas of Machakos Town were likely to adopt capital-intensive technologies compared to those in Wote area. This was attributed to the fact that the farmers had better access to credit in Machakos area than those in Wote area. The limited access to credit by dairy farmers in Wote area was reported to be due to limited credit sources, high interest rates and the high risks associated with defaulting. This finding was consistent with Mamudu *et al*., (2012) that lack of access to credit made it difficult for farmers to afford capital-intensive technologies. This was particularly so given that some modern equipments, like chaff-cutter, were relatively expensive, therefore unaffordable to in the absence of credit facilities. This was in line with Nguthi (2007) who noted that credit or savings was often required to finance the inputs associated with a new technology. Nguthi (2007) also noted that the relationship between financial capital and adoption depended on the characteristic of the technology and the household's resource endowments such as size of land.

Access to extension services was found to be low in peri-urban areas of Wote Town. This was attributed to long distances the farmers had to cover to reach the research centres and few visits by extension officers. Therefore, dairy farmers were not bound to counter balance the negative effects of lack of formal education. This was expected to impact negatively on adoption of technical innovations. However, the dairy farmers in adjacent areas of Machakos Town, who had better access to extension, were bound to acquire relevant information or reduce uncertainties, thus promotes adoption of the innovations. The uptake of new technologies was often influenced by the farmer's contact with extension services, since extension agents provided technical advice to the dairy farmers. This study reveals access to extension services greatly influenced the more technical innovations: fodder crops to enhancing feedstuff supply; TM to enhance moisture retention; hay and silage to preserve excess forage. This was attributed to the fact that access to extension services created platform for acquisition of the relevant information that promoted technology adoption and reduced the uncertainty about a technology's performance.

4.2.2 Adoption and Determinants of Selected Forage Innovations.

4.2.2.1 Adoption of Fodder Crops Technology

Constant feedstuff supply for the intensified dairying in both study areas was a big challenge. This was likely due to frequent rainfall failure and water shortage, which prompted the farmers to start adopting production of high quality fodder crops. This was in agreement with the findings of Wambugu *et al*., (2003) who noted that adopted fodder crops had great potential for increased fodder production and income of smallholder dairy farmers. The adoption of fodder crops was on an upward trend since 2010. This was highly contributed by awareness and necessity created amongst the farmers by extension services during the KALRO/ASARECA project.

Panicum grass was adopted more in peri-urban areas of Wote Town due to its water-stress tolerance traits than in peri-urban area of Machakos Town. Napier and Rhodes grasses were ecologically suited in the wetter areas of Machakos Town than in peri-urban areas of Wote Town. However, the clitoria, which was planted on the edges of farms or terraces, was poorly adopted by dairy farmers in both study areas. This was attributed to its poor establishment and its perceived low relative advantage over other fodder crops, like Napier grass by the farmers. In addition, experience from dairy farmers showed that some legumes, like *Lablab,* were suspected to have a disadvantage of producing off-flavours in milk when fed fresh to lactating animals. The tainted milk was unacceptable to the consumers and resulted into losses for the dairy farmers.

The uptake of fodder crop technology was significantly influenced by vigorous promotion attributed to KALRO/ASARECA collaborative project implemented in these areas. This helped the dairy farmers to have better awareness of importance of the fodder crops to reduce feed scarcity. This finding was in agreement with Mureithi *et al.,* (1998), who reported increased adoption of fodder crops by smallholder dairy farmers in the Central Highlands of Kenya due to improved access to extension services.

The study revealed that farmers who had title deeds for their lands, felt they had secure land rights and assured of continued ownership of the land and were willing to plant fodder crops in their farms. This was consistent with Orodho (2006), who revealed that dairy farmers with individual and secure land ownership invested in improved forage production practices.

Number of dairy cattle kept by households and expected milk yield positively influenced adoption of fodder crops. This was attributed to the fact that dairy cattle were heavy feeders and required large quantity of feedstuffs. Increased number of dairy cattle called for high forage supply to produce the expected high milk yield, which had to be met by adopting the fodder crop technology. Further, in AEZ IV forage production was low and there was need to supplement forage production by growing improved fodder crops. Type of feeding significantly influenced adoption of improved fodder crops. Confined dairy cattle in stall-feeding system required quality feedstuffs obtained from established fodder crops, which were cut and carried and stored in safe and uncontaminated form. Thus farmers using stall-feeding system should be educated through extension services for quality fodder crops, like Napier grass.

Years of experience in dairying significantly and positively influenced adoption of fodder crops. This was in agreement with Kinambuga (2010) and Mukokha *et al.,* (2007) that experienced farmers had better skills of management of dairy cattle and forage. This implies that the young and inexperienced dairy farmers required extension services to improve their forage production.

Gender was found to significantly and negatively influence adoption of fodder crops. This implied that the female-headed households were less likely to adopt fodder crops. This was consistent with Orodho (2005) in a study of intensive forage production for smallholder dairying in East Africa that female farmers were reluctant to adopt labour-intensive improved technologies. This attributes that female headed households were less likely to adopt innovations. This therefore calls for extension services to assist the female-headed households for better forage and dairy production in the semi-arid regions in the south eastern Kenya.

However, age, education, off-farm income or formal employment, farm size, access to credit and membership to co-operative were insignificant in influencing adoption of fodder crops. In effect, this meant that young and old, educated and non-educated farmers belonging to a co-operative or not, with access to credit and off-farm income or not and carrying out dairying on small or large farms were likely to adopt fodder crops in both study areas. This meant that the advantage of better forage yields obtained by the adopters was an enticing factor for higher adoption of fodder crops. This agreed with Rogers (2003) that when adopters see relative advantage in relatively observable cheap and easy-to-adopt innovations they usually adopt.

4.2.2.2 Adoption of Tumbukiza Method Technique

Rainfall failure, shortage of water and lack of skills were the main constraints for good establishment of fodder crops in both study sites. Hence, better ways of trapping rain water and conserving moisture in the soils for longer period and efficient use were necessary. This necessitated adoption of the TM for improved fodder production by the farmers. The adoption of TM required awareness on its applicability and importance. This was likely to be achieved through extension services. For example, KALRO/ASARECA collaborative project had positive impacts on use of TM since 2010 for better soil moisture retention and increased fodder production. This was consistent with Orodho (2007) who revealed that TM was suitable for growing fodder crops in low rainfall areas as it enhanced soil fertility conservation and moisture retention. Further, the retained moisture enhanced fodder growth and its survival through the long dry spells.

Contrary to expectation, age had negative and insignificant influence on adoption of TM. This implied that older farmers were unlikely to not adopt TM. This could be attributed to the fact older farmers were less energetic with limited resources to adopt the labour-intensive TM Technology.

Gender had negative and insignificant influence on adoption of TM. This meant that female – headed households were unlikely to adopt the TM. This could be attributed to the fact that female-heads were less endowed with resources and had less control of resources in male-headed households and they were not likely to adopt labour-intensive technologies easily.

Secure land ownership was very significant factor in determining adoption of TM. This finding agreed with those of Orodho (2007), who found out that farmers with individual/free-hold system (whether titled or not) had secure land rights and adopted long-lasting and initial-labour intensive TM.

Type of feeding significantly influenced TM as the farmers anticipated high requirements of quality feedstuffs for the adopted and stall-fed dairy cattle – which were heavy feeders. This was in line with Wambugu, (2003) and Place *et al*., (2009) that fodder crop production using TM was superior to fodder crop production under the conventional methods.

Access to extension impacted positively on adoption of forage technologies as it created awareness and removed any misconception of implementing the technical TM. The extension services created understanding of importance of TM in retaining moisture in the soils for increased production of fodder crops. This was in line with Place *et al.*, (2009) who found out that TM conserved moisture in the soils and fodder crops had prolonged production in the dry season. This is likely to entice the farmers to adopt the TM. In addition, educated farmers adopted the TM technique as the formal education created better visualization and understanding of concept of TM. It is therefore necessary for extension agents to educate illiterate farmers to improve their understanding of the TM technology.

Expected milk yield acted as a catalyst and drive to entice the dairy farmers to increase their production. This was achieved through sufficient supply of feedstuffs obtained from adopted TM. Increased number of dairy cattle demanded increased forage supply. This is achievable through adopting TM. This implies that TM should be adopted by small-holder farmers with many cattle, kept in stalls, to reduce feed scarcity.

Family size was found to be crucial in adoption of labour-intensive TM. This was attributed to the fact that family members supplied the needed labour especially for digging the pits. This implies that small-sized households should hire labour in order to adopt the TM

Farm size negatively influenced adoption of TM. This was attributed to the fact the small-sized farm faced shortages of feedstuffs and farmers needed the TM technology to reduce feed scarcity. Extensive farms that seemed to have adequate feedstuffs were not likely to adopt the TM.

Years of experience in dairying significantly and positively influenced adoption of TM. This was in agreement with Kinambuga (2010) and Mukokha *et al.,* (2007) who reported that experienced farmers had better skills of management of dairy cattle and forage. Thus experienced dairy farmers could plan and strategize their feed supply by adopting TM for improved dairying. This implies that the young and inexperienced dairy farmers required extension services to improve their forage production and consequently the dairy enterprises.

Intensification of dairying influenced adoption of TM. This was attributed to fact that intensified dairying called for increased feed supply in the dairy farms. With the farmers faced feed scarcity, adoption of the TM was deemed necessary. This implies that extension agents need to work with these farmers in order to improve adoption of TM for better fodder production.

Formal employment and membership to a co-operative society were insignificant in influencing adoption of TM. This implied that all farmers had equal likelihood of adopting the TM.

4.2.2.3 Adoption of Feed Chopping Technique

Faced with feed constraints and high labour costs and change of grazing systems, most dairy farmers adopted chopping technique. They were using mostly simple traditional devices, like *pangas*, which were affordable to enhance utilization of feedstuffs and minimize wastage. In addition, improved choppers – chaff-cutter and fixed knife cutter– were advocated for but their adoption level was low. However, adoption of chopping technique was relatively lower in Wote than in Machakos. This was attributed to high availability of feedstuffs in peri-urban area of Wote Town than that of Machakos Town. However, use of improved chaff-cutter and fixed knife cutter was low in both study areas due to their high initial cost, hence, not affordable to most farmers.

Educated farmers adopted the improved chopping technique than the less educated as they could understand the working of complex chopping equipment better. This was attributed to the fact that education influences knowledge, understanding and creates a positive attitude for the acceptance of new innovations. Also the educated farmers could have better income and therefore could afford the chaff-cutters.

Farmers with access to affordable credit highly adopted the improved chopping technique, using the fixed knife cutter and the expensive motorized chaff-cutter. This, in effect, increased the supply of finely chopped feedstuffs to the stall-fed dairy cattle. This was consistent with adoption theory by Rogers (2003) that more complex and expensive innovations are less likely to be adopted by resource-poor. However, adoption improves if access to affordable credit is available to the dairy farmers

The dairy farmers aimed at producing increased milk yield to meet the increased milk demand. This explained why expected milk yield was crucial in influencing adoption of chopping technique. Forage chopping ensured constant supply of quality silage feedstuffs to the dairy cattle as well as it ensured minimal wastage of forage during feeding. This was consistent with Schreiber (2002) who noted that adequate feed rations to the dairy cattle increases milk yield.

Family size and farm size impacted negatively on adoption of chopping of feedstuffs. Households with large family had adequate labour and were not bound to adopt labour-saving technology. In addition, large farm size correlated positively to increased availability of feedstuffs to the dairy cattle. These farms were not bound to face feed scarcity, thus they were unlikely to bound adopt efficiency-enhancing technologies.

Intensified dairying, in stall-feeding, influenced the adoption of chopping technique. This was attributed to fact that in intensified stall-fed dairying require high quality feedstuffs utilized with minimal wastage. This, therefore, necessitated these farmers to adopt the chopping for better dairy production. This implies that extension agents need to educate these farmers through extension services in order to improve forage utilization.

Other variables tested in the model were insignificant in influencing the adoption of chopping technology. This implied that male or female-headed households or employed or not, with individual or other forms of tenure systems had equal likelihood to adopt chopping technique.

4.2.2.4 Adoption of Silage Making

Most dairy farmers viewed silage making as technical and an expensive innovation and were reluctant to adopt it. This contributed to the low levels of adoption of silage making in peri-urban areas of Wote and Machakos Towns. This finding supports those of Moran (2005) who noted a low level of adoption of silage making among small-scale dairy farmers in humid tropics. In addition, some dairy farmers reported that they had fear of producing poor silage, due to mould problem, which was likely to affect their dairy cattle and their feed intake or milk produced. Further, polythene bag silage making was lowly adopted in both study areas. This was attributed to the technical handicap and the numerous constraints the farmers faced especially mould formation. These were suspected to discourage the farmers especially the less educated farmers.

The likelihood of adoption of silage making was significantly influenced by the years of experience in dairying. Experienced dairy farmers acquired lessons and skills over time. These skills were necessary to understand the principles and steps of the silage making. This is supported by Moran (2005) who highlighted that experience was important for adopters to learn from their mistakes and improve their skills in feedstuff management. This meant that extension agents could work with inexperienced dairy farmers to improve their skills. These inexperienced farmers can also gain skills from the experienced dairy farmers.

Access to extension was equally crucial. Extension provided the awareness and information on the right methodology and conditions of making silage. This meant that access to extension services was paramount for continued adoption of silage making among the dairy farmers.

Education had significant contribution to adoption of silage making. This was attributed to the fact that education created better understanding of concepts and principles of silage making. In addition, education is also associated with more resources or income. This explains why educated farmers were significantly adopting silage making than less educated farmers. This implies that less educated dairy farmers need better extension services.

Silage making being expensive and labour-intensive, access to credit was crucial. It was necessary to provide reliable sources of funds required to purchase inputs - polythene bags and molasses- for efficient silage making. Access to credit increased the likelihood of dairy farmers in adopting silage making. This implied that the resource-poor dairy farmers required credit facilitation in order to improve on silage making in their farms.

Formal employment was found to be crucial in influencing adoption of silage making. This was attributed to the fact that employment provided off-farm income that could be used to purchase the needed inputs for silage making from the adopted fodder crops and other forage materials to increase the milk yields. This meant that credit facilitators should pay more attention to the non-employed farmers (who were in need of credit) to improve their financial assistance.

Land tenure system had its share of influence on adoption of silage making. Silage making require the use of high quality forages. These feedstuff materials were obtained from long-term adopted fodder crops which were grown on farms with secure ownership of land. This meant that the dairy farmers with secure ownership of land, planted quality fodder crops, whose herbage was used in silage making.

Expected milk yield was an influential factor on adoption of silage making. The high milk yield was a drive that enticed the dairy farmers to improve the quality and quantity of feedstuffs. This necessitated the dairy farmers to make quality silage that the dairy farmers used as dairy supplement. This was in line with Moran (2005) who noted that conserved quality silage was significantly important for intensified dairying.

4.2.2.5 Adoption of Hay–Making

As per literature review hay making is an easier way of conserving excess forage. This, together with advocacy of importance of hay making by KALRO/ASARECA's project in the two study sites, could be an explanation to why the adoption of hay making has been increasing since 2010. This could also be contributed by the feed constraints imposed by the intensified dairy production and positive effects of access to extension. This was consistent with Schreiber (2002) and Karugia (2012) that dairy farmers significantly cushioned feed constraints by adopting hay making. However, adoption level of hay making has remained low in both study areas. This was attributed to the numerous constraints the dairy farmers were facing, like inadequate forage occasioned by low production and seasonal fluctuations in these areas.

Adoption of intensified stall-feeding was positively influenced adoption of hay making. This was attributed to the fact that adopted dairy cattle, kept in stalls or cowsheds, required constant supply of uncontaminated feedstuffs. However, as reported by Amwata (2013), forage production in the ASALs is normally low and fluctuated between seasons. This necessitated the dairy farmers to cut the excess forage in the wet season and stored it in modern HB for the stall-feeding. The stored feedstuffs were safe and didn't affect the cattle. This was consistent with Moran (2005) who noted that adopted hay barn ensured that the stored feedstuffs were free from aflatoxin or were not rotten and was able to reduce the problem of feed scarcity.

Education increased the likelihood of adoption of hay making by the farmers. Education created understanding of the importance and principles of hay making. This meant that less educated dairy farmers were unlikely to adopt hay making. This implied that the extension agents needed to train these farmers in order to improve their feed supply especially in the dry spells.

Years of experience in dairying significantly influenced adoption of hay making. This was attributed to the fact that the experienced farmers learnt and adapted ways to reduce the feed scarcity in their dairy enterprises. This implied that the inexperienced dairy farmers were not likely to adopt hay making. This called for the extension agents to train the inexperienced dairy farmers on principles of hay making in order to improve their feed supply.

The desire of the dairy farmers to produce high milk yields acted as a drive in adopting the hay making. Feed supply fluctuations between seasons in the ASALs are common phenomena and this greatly affects milk supply and income generated from milk sales. This enticed the farmers to adopt hay making to conserve the excess forage to ensure that the expected milk yields were realized even in the dry seasons. This agreed with Schreiber (2002) and Moran (2005) who noted that conserved hay encouraged the dairy farmers to increased milk production.

4.2.2.6 Adoption of Hay Barn Technology

Most dairy farmers had adopted modern hay barn to conserve mostly crop residues and specifically maize stovers, hay and silage. These dairy farmers aimed at economizing the scarce feedstuffs obtained from fodder crops, crop residues and pastures. The use of HB for storage of feedstuffs ensured constant supply of quality and safe feedstuffs for the dairy cattle. This was consistent with Moran (2005) who noted that that HB preserved feedstuff in hygienic conditions and reduce damage from rains and development of aflatoxin infestation. However, some dairy farmers used rudimentary methods that exposed conserved feedstuff to rains and aflatoxin and risked the health of the animals and consumers of milk and meat.

In the semi-arid regions of South Eastern Kenya, feed scarcity is frequent over the seasons and dairy farmers have became adaptive and innovative by adopting HB technology. This accounted why old dairy farmers, with many years of experience in dairying and feedstuffs management, adopted the HB to conserve feedstuffs for use in dry spells. These findings were consistent with those of Ouma *et al*., (2007) that adoption of intensified stall-feeding, improved fodder crops and hay making necessitated adoption of better storage means of feedstuffs.

Extension played no crucial role in the adoption of modern HB. This was attributed to fact the hay barns were observable and their relative advantages could easily be seen. Furthermore, HB was widely practiced and farmers could emulate the technology from neighbours. However, through extension services, the farmers were educated on the essentials of conserving the feedstuff in the HB. The implication was that farmers became aware of dangers of the aflatoxin poisoning from water contaminated forages. In addition, the dairy farmers were educated on maintenance of HB to ensure the excess harvested forage and crop residues and prepared feedstuffs, like silage and hay, were stored safely. This was important so that the dairy farmers don't loose the chopped feedstuffs or stored feedstuffs through rain damage and contamination.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The study showed that the male headed households were dominant in dairy farming in the two study areas; with their average education being secondary school level. Most of the dairy farmers were at their productive age and had medium family size. Most of the dairy farmers had free-hold land system that ensured secure ownership of land. This was an enticing factor for the dairy farmers to adopt long-term innovations on their average sized farms in both study areas. Further, most dairy farmers had formal employment from which they obtained off-farm income but, however, the dairy farmers had limited access to credit and extension services in Wote peri-urban area compared to Machakos peri-urban area.

Faced with livelihood-threatening challenges and the drive to produce milk to meet the high milk demand, the farmers adopted dairying as livelihood support and income-generating activity. However, the intensity of stall-feeding production and milk production were found to be low due to use of dairy cattle of unknown genetic value, breeding and feed and feeding constraints. This necessitated further adoption of improved forage and labour-saving innovations aimed at increasing smallholder production at economical scale to meet milk demand in these ASALs’ peri-urban environs in the South Eastern Kenya.

The study revealed that the farmers adopted AI for breeding purposes. However, its adoption was highly construed by the high charges for AI services. This remains an impediment in realizing high milk production and hence remedial interventions are needed.

Feed constraints being common and feed requirements for the confined dairy cattle being high, the farmers adopted fodder crops, like Napier and Rhodes grasses and leuceana and *Lablab* legumes to mitigate these constraints and meet the requirements of the dairy cattle. However, better sources are needed to ensure the farmers have adequate supply of the planting materials. Extension services are required to address the challenges of establishing the fodder crops. This can be achieved through increased visits to the farmers especially the old farmers and female-headed households. Furthermore, land adjudication need to be completed to ensure that the farmers have security of land ownership. This will entice the farmers to adopt labour-intensive and long-term innovations in their farms.

Due to change of production system towards sedentary stall-feeding and high fluctuations of feedstuffs, the dairy farmers adopted conservation methods to store the excess forage. Hay conservation, found to be less technical, was the commonly used method compared to the more technical silage making. However, baling of hay was low due lack of adequate feedstuffs and skills and equipments. Further, adoption of intensive stall-feeding dairying significantly influenced adoption of hay making. Silage making, which had low adoption percent, was mainly affected by mould formation. Years of experience in dairying and access to extension were critically influential in adoption of silage for supply of quality silage.

In their endeavour to increase efficiency of utilization of harvested and conserved feedstuffs and silage making, dairy farmers adopted the chopping innovation. However, chopping was mostly done using traditional *panga* – which was pointed out to be tedious, time-consuming and less efficient for intensified stall-fed dairying. Faced with this impediment, only few able dairy farmers adopted modern chopping equipment to increase efficiency of utilization of feedstuffs, increase silage making and reduce wastage of feedstuffs. This calls for increased interactions between the old and young, literate and less educated farmers in order for the farmers to learnt from each other and increase their skills. This will have significant influence adoption of chopping and conservation innovations.

Faced with risk of loss and contamination of conserved feedstuffs (crop residue, hay or silage) due to rain damage and aflatoxin infection, the farmers adopted HB technique for storage of feedstuffs in dry hygienic conditions. However, due to damage by termites and lack of credit other rudimentary storage forms were still being used by some farmers. This calls for increased access to extension services and credit facilities to significantly influenced adoption of HB in the study areas.

5.3 RECOMMENDATIONS

There is need to address the problems faced by peri-urban dairy farmers in these semi-arid regions of South Eastern Kenya in a holistic way to enhance adoption of forage and labour-saving innovations and better milk production. The results from this study necessitate several recommendations.

- High quality fodder crops (grasses and legumes) needs to be adopted to enhance forage production and alleviate feed scarcity. These fodder crops need to be utilized through the cut-and-carry feeding system for efficient and prolonged feed supply.
- Napier and Rhodes grasses and *Clitoria* legume were found to be suitable for adoption in the UM of Machakos Town while *Panicum* grass and *Lablab* legume are suitable for forage production in LM of Wote Town. In order to ensure continuous supply of planting materials, there is need for multiplication of the planting materials at the farm-level to increase its supply for better forage production.
- TM technology needs to be adopted to enhance moisture and soil fertility in the forage production for prolonged and increased forage supply. Improved water harvesting techniques need to be adopted to increase water supply for the dairy and forage production. Furthermore, there was need to train the older dairy farmers and female households heads on the TM to increase its adoption. In addition, slurry from the stall-feeding units should be added into the TM pits to enhance fodder production and the dairy farmers rearing their cattle in Zero-grazing units need to adopt the TM for continued supply of quality feedstuffs.
- Extension services need to be revitalized for farmers to receive more information and advice on the forage production and labour-saving innovations. More technical personnel need to be engaged in order to raise awareness, create positive attitude and explain workability of the technical innovations, like silage making and chopping in the two sites.
- Revitalization of the co-operative movement to enable the farmers to obtain credit (without collateral), farm inputs and assist in marketing of their milk or adding value of the milk through processing need to be facilitated.
- Land adjudication and issuance of title deeds need to be hastened especially in Makueni County for farmers to have secure land rights and adopt long-lasting innovations. This will enable the farmers to have collateral when securing for loans.

- Ongoing activities to promote the forage technologies and their adoption among the dairy farmers or farmer groups should continue, with increased emphasis on how they can improve members' access to information.
- Access to relevant network of information centres needs to be improved through effective partnerships between existing public resources and private sector actors for all dairy and livestock farmers.

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APPENDIX 1: Additional Figures and Tables

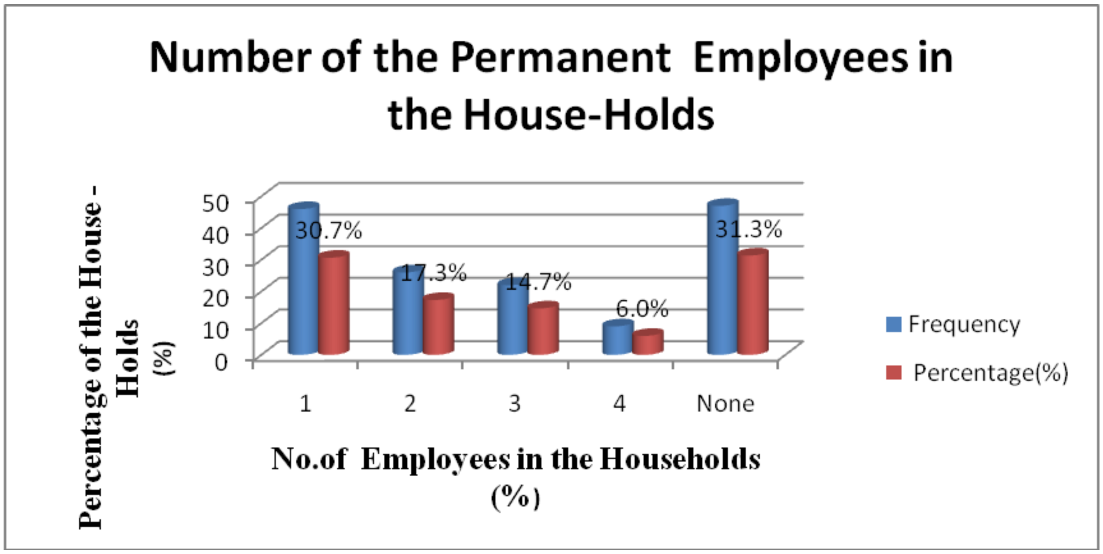

Figure 4.8: Range of Permanent Employees in the Households

Table 4.29: Frequency of Number of the Land units Owned by Household (n=150)

Division	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Central	38	24	5	1	1	0	1	70
Wote	47	18	14	0	0	1	0	80
Total	**85**	**42**	**19**	**1**	**1**	**1**	**1**	**150**

Table 4.30: Frequency of Average Distance between the Land Units (Km) (n=150)

Division	**None**	**¼**	**½**	**¾**	**1**	**1 ½**	**1 ¾**	**2**	**> 3**	**Total**
Central	38	2	6	8	5	4	3	2	2	32
Wote	47	1	5	0	12	7	5	3	0	33
Total	**85**	**3**	**11**	**8**	**17**	**11**	**8**	**5**	**2**	**65**

Table 4.31: Extent of Adoption of Forage Technologies based on Extension

	Number of Adopters	Engaged by KALRO (N=120)		Not engaged by KALRO (N=30)		**χ2 (p-value)**
		Frequency	Percent	Frequency	Percent	
Fodder Crop	54	50	41.7	4	13.5	12.02 (.02*)
Tumbukiza Technique	67	60	50.0	7	23.3	4.84 (.032*)
Hay making	31	28	23.3	3	10.0	3.31 (.046*)
Silage Making	18	16	13.3	2	6.7	1.91 (.028*)
Chopping Technique	129	108	90	21	70.0	2.26 (.087)
Hay Barn Technique	109	89	74.2	20	66.7	5.83 (.076)

***Significant at P<0.05**

APPENDIX II: Definitions of Terminologies

Definition of some of the terms such as vulnerability and risk, vary among disciplines and contexts. In these cases, broad definitions are provided along with alternative definitions where applicable as shown below as defined by FAO/ United Nations standards.

Adaptation: Refers to changes in processes, practices or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes.

Adoption: Refers to a process composed of learning, deciding and acting over a period of time.

Extension: Refers to essentially education of disseminating agronomic techniques and skills to farmers with aim of bringing about positive behavioral changes among farmers.

Food security: Refers to the degree of food availability, access to food, stability of food supply and utilization.

Household: Refers to a person or group of persons generally bound by ties of kinship who live together under a single roof or within a single compound and who share common way of life in that they are answerable to the same head and share a common source of food.

Livelihood: Refers to actions or other incentives of persons or society or the community used economically to influence their behavior.

Poverty: Refers to the state in which one lacks certain amounts of material for sustaining descent livelihoods or it is pronounced deprivation in well-being – low incomes and inability to acquire basic goods and services.

Resource: Refers to assets which are physical, natural, economic, or financial which enable the production of goods and services in the household or production unit.

Sustainable livelihoods: Refers to livelihoods that can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets both now and in future while not undermining the natural resource base.

Vulnerability: Refers to set of conditions resulting from physical, social, economic and environmental factors, which increase the susceptibility of the community or persons to the impact of disasters or Refers to the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of the natural hazard.

APPENDIX III: Questionnaire

You have been selected among other farmers to assist in providing information on the level of selected dairy and forage technologies, challenges, constraints and determinants of adoption of each innovation. The information you provide will be used for academic purposes in South Eastern Kenya University. Please give correct information as possible for it to be useful in the research and it will be treated confidentially.

A: GENERAL INFORMATION OF THE HOUSEHOLD

A1. Household Identification

Village ______________ Sub-Location________________ Location______________

Division______________ County /AEZ 1 Machakos 2 Makueni

A2. Particulars of the Respondent

Name of Respondent ___________ Gender 1 Male. 2. Female.

Age.____________ Occupation.____________ Contact (Tel. No.)__________________

A3. Name of Head of Household________ Gender 1 Male 2 Female.

Age_________ Primary Occupation 1.Farming 2.Civil Service 3.Business 4.NGOs/CBOs 5.Others (specify)___________

B: CHARACTERISTICS OF THE HOUSEHOLD

Fill in the information of Household characteristics in the columns of the table below

*Coding for the Answers shown in the second Row (Where possible).

Family Size (For all members of Household) ***Tick the Choice as appropriate***	Number of the Member in Household (Exclude Employee) ***List order of the members**	Gender of the Number of the Member? ***Fill the choice as appropriate for the Member**		Relationship of the number to Household Head ***Fill the choice as appropriate for the Member**	Age of the Number? ***Fill the choice as appropriate for the Member**	Highest level of Education attained by the Number? ***Fill the choice as appropriate for the Member**	Occupation of the Number? ***Fill the choice as appropriate for the Member**	Number of the member who provides family labour (Tick)
B 1	**B 2**	**B 3**		**B 4**	**B 5**	**B 6**	**B 7**	**B 8**
1. 2 2. 3 3. 4 4. 5 5. 6 6. 7 7. 8 8. 9 9. 10		1.Male (M) 2.Female(F)		1.Spouse 2.Child 3.Relative 4.Orphan 5. Other		1.None 2.Primary 3.Secondary 4.Post-Secondary 6.Adult 7.Others(specify)	1.Below Schooling age(<4 yrs) 2.Schooling Age 3.None - old age(>70yrs) 4.Farming 5. Employed 6.Others(specify)	
		M	F					
	1.							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							

B9i). State the number of employed personnel in your farm

1. One 2. Two 3. Three 4. Four 5. Five 6. Others (Specify)

B9ii). State of Income 1. Adequate 2. Inadequate

B9ii) Off-farm Income 1. Yes 2. No

B10. Labour Division in the Farm.

Tick (√) as appropriate in the table below. ****Enumerator to observe where possible for validation***

Farm Activity / Labour Division			Herding/feeding of the livestock		Farm preparation & feedstuff planting/weeding		Feedstuff harvesting & conservation practices		Milking of the cows		Marketing of the milk	
B10			B11		B12		B13		B14		B15	
			M	F	M	F	M	F	M	F	M	F
Family Labour	B10i	Spouse										
	B10ii	Children										
	B10iii	Orphan										
	B10iv	Grandparents										
Employee Labour	B10v	Permanent										
	B10vi	Casuals										
Self-help Group Labour	B10vii											

C: LAND TENURE AND FARM UTILIZATION.

Fill in the information of land tenure and farm utilization in the columns of the table below

*Coding for the Answers shown in the second Row (Where possible).Tick (√) *as appropriate* or Fill the blank spaces

Size of the Farm (Ha) ***Tick the Choice as appropriate***	Land Tenure System ***Tick the Choice(s) as appropriate***	Acreage (Ha) of land allocated for the Different purposes				No. of Land Units ***Tick the Choice as appropriate***	Average distance between them (KM)
C 1	C 2	C 3				C 4	C 6
1. 1 2. 2 3. 3 4. 4 5. 5 6. 6 7. 7 8. 8 9. 9 10. 10 11. 11 12. 12 13. Others (Specify)	1. Communal 2. Free-hold 3. Leasehold 4. Hired/Rented 5. Donated 6. Public 7. Customary 8.Others	Homestead C3-i ***Tick the Choice(s) as appropriate*** 1. 1/8 2. ¼ 3. 1/2 4. ¾ 5. 1 6. 1 1/4 7. 1 1/2 8. 1 3/4 9. 2 10. Others (Specify)	Crops C 3-ii ***Fill in the Value in the space provided** ________	Livestock C 3-iii ***Fill in the Value in the space provided** ________	Others C 3-iv ______	1. 1 2. 2 3. 3 4. 4 5. 5 6. 6 7. Others	1. None 2. ¼ 3. 1/2 4. ¾ 5. 1 6. 1 1/2 7. 2 8. 3 9. Others (specify)

D: LIVESTOCK KEPT IN THE FARM. Fill in the information of livestock kept in the farm in the columns of the table below**,***Coding for the Answers shown in the second Row (Where possible):

*For bees Kept, Indicate the Number of Beehive the Farmer has in his/her farm in column of Indigenous breeds

Type of Livestock	Number of Indigenous Breeds	No. of Animals of Exotic Breeds	No. of Animals of the Cross Breeds	Objective of the Livestock
	1. None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. Others	1. None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. Others	1. None 2 1 3 2 4 3 5 4 6 5 7 6 8 Others	1.Milk 2.Meat 3.Egg 4.Animal Power 5. Skin and Hides 6.Social Obligations 7.Manure 8.Cash/Income 9.Honey
D 1 ***Tick(√) the types Kept***	D 2 ***Indicate the No. of each type of Livestock***	D 3 ***Indicate the No. of each type of Livestock***	D 4 ***Indicate the No. of each type of Livestock***	D 5 ***Indicate the Code of objective(s) as per each type of the livestock***
1. Cattle				
2. Goats				
3. Sheep				
4. Donkeys				
5. Chickens				
6. Ducks				
7. Turkeys				
8. Pigeons				
9. Quails				
10. Bees.				
11. Others				

D 6.Tick the most preferred livestock 1 Indigenous 2 Exotic 3 Cross Breeds 4 None

D 7.Tick the most profitable Livestock 1 Cattle 2 Goats 3.Chickens 4 Sheep 5 others (Specify)

D8. Do you carry out dairying production in your farm 1. Yes 2. No

E: DAIRY BREEDS KEPT-HERD STRUCTURE

Fill in the information of dairy breeds kept in the farm in the columns of the table below

*Coding for the Answers shown in the second Row (Where possible).

Type of the Breed	No. of Animal of the Dairy Cattle Breed E 2		Where did you obtain the breeds	Breed of cattle easily available	Basis of selecting Dairy cattle Breeds (Tick on the corresponding box)
	Before 2010	By 2012			
	1. None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. 7 9. 8	1. None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. 7 9. 8	1.Neighbour 2.Local Market 3.Auctions 4.ASK Shows 5.Central Highlands 6.Rift Valley 7.Others(Specify)	1.Friesian 2.Guernsey 3.Aryshire 4.Jersey 5.Sahiwal 6.CrossBreed	1. Milk Yield 2.Disease Resistant 3.Well Adapted 4.Easy to Manage 5.Only Breed available 6.Extension requirement 7.Others(Specify)
E 1 ***Tick(√) the Breeds Kept***	**E 2 i** ***Indicate the No. as per each Breed***	**E2 ii** ***Indicate the No. as per each Breed***	**E 3** ***Indicate the Code(s) as per each Breed***	**E 4** ***Indicate the Code(s) as per each Breed***	**E 5** ***Indicate the Code(s) as per each Breed***
1. Friesian					
2. Aryshire					
3. Guernsey					
4. Jersey					
5. Sahiwal					
6. Brown Swiss					
7. Cross Breeds i.Friesian × Local Breed					
ii. Aryshire × Local					
iii. Guersney× Local					
iv Jersey× Local					
v. Sahiwal × Local					
8. Others(specify)					

E6. How long have been doing Dairy Farming:____________________________________(Indicate the period in years)

F: DAIRY HERD COMPOSITION: Fill in the information on dairy herd composition in the farm in the columns of the table below**;** *Coding for the Answers shown in the second Row (Where possible).

Type of Breed ***Tick(√) the type of Breed***	Calves ***Indicate the No. of Calves as per sex for different Breeds kept***		Heifers ***Indicate the No. of Heifers for different Breeds kept***	Young Bulls ***Indicate the No. of Young Bulls for different Breeds***	Lactating Cows ***Indicate the No. of Lactating Cows for different Breeds kept***	Dry Cows ***Indicate the No. of Dry cows for different Breeds kept***	Mature Bulls ***Indicate the No. of Mature Bulls for different Breeds kept***
Codes for the different choice(s) for the respective Columns→	1. None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. 7 9. 8 10. 9 11. 10 12. Others		1. None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. 7 9. 8 10. 9 11. 10 12. Others	1. None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. 7 9. 8 10. 9 11. 10 12. Others	1 . None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. 7 9. 8 10. 9 11. 10 12. Other	1. None 2. 1 3. 2 4. 3 5. 4 6. 5 7. 6 8. 7 9. 8 10. 9 11. 10 12. Others	1.None 1. 1 2. 2 3. 3 4. 4 5. 5 6. 6 7. 7 8. 8 9. 9
F1	**F2**		**F3**	**F4**	**F5**	**F6**	**F7**
	F2-i	**F2-ii**					
	Male	Female					
1. Friesian							
2. Aryshire							
3. Guernsey							
4. Jersey							

5. Sahiwal							
6. Brown Swiss							
7. Cross Breeds i.Friesian × Local Breed							
ii. Aryshire × Local							
iii. Guernsey × Local							
iv. Jersey × Local							
v. Sahiwal× Local							
8. Others(specify)							

G: DAIRY HERD DYNAMISM

Fill in the table for information requested.

Category of Dairy animal	No. of Animals Bought		No. of Animals Sold		Reasons for	
G1	**G2**		**G3**		**G4**	
Tick(√) the category or Categories of Dairy Animal	2010	2012	2010	2012	Purchase	Sale
	G2-i ****Indicate the No. as per each***	**G2-ii** ****Indicate the No. as per each***	**G3-i** ****Indicate the No. as per each***	**G3-ii** ****Indicate the No. as per each***	**G4- I** ****Indicate the Reason as per each***	**G4-ii** ****Indicate the Reason as per each***
1. Male calves						
2. Female calves						
3. Heifers						
4. Cows						
5. Mature Bulls						
6. Others(Specify)						

H: DAIRY IMPROVEMENT PRACTICES

H1i.Do you use AI services? 1. Yes 2 No

ii). If no, what other breeding technique(s) do you use? 1. Bulls 2 Embryo Transfer

H2. If A.I services are used, Tick the appropriate choice(s) in the table below for information sought.

What is the Source of A.I ***Tick the Choice(s) as appropriate***	What is the availability of the A.I. ***Tick the Choice(s) as appropriate***	What is the success of the A.I Services ***Tick the Choice(s) as appropriate***	What are the charges of the A.I ***Tick the Choice(s) as appropriate***	What are the major constraints of using the A.I***Tick the Choice(s) as appropriate***
H 2-i	**H 2-ii**	**H 2-iii**	**H 2-iv**	**H 2-v**
1.Other Farmer	1. Readily Available	1. Very successful	1. 1000/=	1. High charges
2.Private Practitioner	2. Fairly Available	2. Fairly successful	2. 1500/=	2. Unavailability
3. Government Vet. Officer	3. Rarely available	3.Rarely Successful	3. 2000/=	3. Failure of the AI
4.NGO/CBOs	4. Hardly Available	4. Not successful	4. 2500/=	4.Negative Altitude
5.Co-operative Society	5. Non- applicable	5. Others(Specify)	5. 3000/=	5.Poor infrastructure
6. Others(specify)			6. 3500/=	6.Unskilled personnel
			7. 4000/=	7.Others(Specify)
			8.4500/=	
			9.Others(Specify)	

H3. If bulls are used; Tick the appropriate choice(s) in the table below for the information being sought.

What are the sources of the bulls***Tick the Choice(s) as appropriate***	What type of bulls are used ***Tick the Choice(s) as appropriate***	How is the availability of Bulls ***Tick the Choice(s) as appropriate***	What is the charges of use of the bulls ***Tick the Choice(s) as appropriate***	What are the major constraints and problems of the use of Bulls ***Tick the Choice(s) as appropriate***
H3-i	**H3-ii**	**H3-iii**	**H3-iv**	**H3-v**
1. Own Bulls	1. Local Bulls	1.Easily available	1. Free	1.Scarcity of Proven Bulls
2.Neighbour Bulls	2. Pure Exotic Bulls	2.Fairly Available	2. 100/=	2. Inbreeding
3.Others(specify)	3.CrossBred Bulls	3.RarelyAvailable	3. 300/=	3.Breeding Diseases
	4. Others(specify)	4.Others (Specify)	4. 400/=	4.Scarcity of Feedstuffs
			5. 500/=	5.Infertility

				6.Physical Injuries
				7.Others(Specify)

I: PASTURE/FODDER ESTABLISHMENT: Fill in the information of pasture/fodder establishment and production in the farm in the columns of the table below. *Coding for the Answers shown in the second Row (Where possible).

State the type of pasture/fodders in your farm	State the year of establishment of the pasture / fodder crops	Where did get the planting material	State the availability of the planting material	How is the timeliness of the planting material	State the cost of the planting Material	What are the 3 major constraints of pasture/fodder establishment
Codes for the different choice(s) for the respective Columns →	1.Planted before 2010 2.Planted 2010 3.Planted 2012	1.Neighbours 2.NGOs 3.CBOS 4.Govt 5.KARI 6.Agro-vets/Manufacturers 7.Others(specify)	1.Very good 2.Good available 3.Fairly available 4.Not available 5. Others (specify)	1.On time 2.Start of wet season 3. Mid of Wet season 4.Late in the wet season 5. Dry season 6.Other(specify)	1 None/Free 2. 100/=/Kg 3. 200/=/Kg 4. 300/=/Kg 5. 400/=/Kg 6. 500/=/Kg 7. 600/=Kg 8.Others(specify)	1.Unavailability of planting Materials 2. Expensive materials 3.Water Shortage 4. Lack of skills 5.Lack of labour 6.Other Business 7. Poor management 8.Others(Specify)
I 1 ***Tick the Choice(s) as appropriate***	I 2 ***List the code(s) of Choice(s) as appropriate***	I 3 ***List the code(s) of Choice(s) as appropriate***	I 4 ***List the code(s) of Choice(s) as appropriate***	I 5 ***List the code(s) of Choice(s) as appropriate***	I 6 ***List the code(s) of Choice(s) as appropriate***	I 7 ***List the code(s) of Choice(s) as appropriate***
1.Planted grass						
2.Planted Shrubs						
3.Planted legumes						
4.Others(Specify)						

I 8.State the methods you use to improve your pasture production:

1.Bush Clearing. 2.Reseeding 3.Use of certified planting materials 4.Others(Specify)

I 9. i). Have adopted fodder crop technique in your farm 1 Yes 2. No

ii).If no, what are the reasons for non- adoption of the fodder crop technique?

1. Not heard. 2. Lack of Planting Materials 3.Lack of Know- how 4.Expensive 5. Shortage of Labour

6. Others(Specify)

J: PASTURE / FODDER CROPS DATA.

Fill in the information of Pasture / Fodder crops data in the farm in the columns of the table below: *Coding for the Answers shown in the second Row (Where possible).

What is the specific type of pasture / Fodder Crops	What is the technique used for planting	State the type of planting material used	Where applicable, state the No. of Planting Pits (Fill the blank spaces)			Where applicable, state the Amounts. of Planting used (Fill the blank spaces)		State the success rate of the planting technique	State the yield of the Pasture/ Fodder Crop harvested.(*Unit used 90Kg gunny bag or Bales or Carts per season ****Enumerator to indicate the unit used by the Farmer***				Acres of the Planted areas	
J 1 ****Tick the Choice(s) as appropriate***	**J 2** ****List the code(s) of Choice(s) as appropriate***	**J 3** ****List the code(s) of Choice(s) as appropriate***	**J 4** ***Fill in the Value in the space provided Below**			**J 5** ***Fill in the Value in the space provided**		**J 6** ****List the code(s) of Choice(s) as appropriate***	**J 7** **2010** ***Fill in the Value in the space provided**		**J 8** **2012*Fill in the Value in the space provided**		**J 9**	
			J 4-i	J4-ii	J4-iii	J5-i	J5-ii		J7-i	J7-ii	J8-i	J8-ii	J9-i	J9-ii
Coding for the answers →	1.Planting Pits 2.Ridges on bench terraces 3.Fanya Juu 4.Others	1.Cutting 2.Splits 3.Local Seeds 4.Certified Seeds 5.Vines 6. Others (Specify)	2010	2012	Total 2012	2010	2012	1.Excellent 2.Good 3.Average 4.Fair 5.Poor 6.Fail	Wet	Dry	Wet	Dry	2010	2012
1.Napier grass			__	___	__	____	____		____	___	____	___	__	__
2.Panicum grass			__	___	__	____	____		____	___	____	___	__	__
3.Lablab			__	___	__	____	____		____	___	____	___	__	__
4.Lucerne			__	___	__	____	____		____	___	____	___	__	__
5.Calliandra			__	___	__	____	____		____	___	____	___	__	__
6.Leuceana			__	___	__	____	____		____	___	____	___	__	__
7.Rhodes Grass			__	__	__	____	____		____	___	____	___	__	__
8.Clitoria species			__	___	__	____	____		___	___	___	___	__	__
9. Others(specify)			__	__	__	__	__		__	__	__	__	__	__

J 9. May you rank the three (3) most successful pasture and fodder crops in your farm(Start with the Most successful)

i.__Napier+Panicum+Rhode______________________________iv.Rhodes+Napier+Panicum______________________________

ii.__Napier+Rhodes+Panicum_____________________________v. Others(Specify)______________________________________

iii__Napier +Panicum+Lablab____

J10. May you rank the three (3) major constraints in establishment of the pastures and fodder crops in your farm

i.____

ii.____

iii____

K: PASTURE AND FEEDSTUFF UTILIZATION

Fill in the information of pasture and feedstuff utilization in the farm in the columns of the table below

*Coding for the Answers shown in the second Row (Where possible).

What is grazing /Feeding system is used in your farm	How many hours are the animals grazed or stall-fed		What are the materials used for supplementary feeding		What is the time of supplementary feeding	What are the average amounts of supplements used		What is the frequency of supplementary feeding	
Coding for the answers ⟶ ***Tick the Choice(s) below as appropriate***	1. 4hrs 2. 5hrs 3. 6hrs 4. 7hrs 5. 8hrs 6. 9hrs 7. ***Fill the code(s) above in the spaces below as appropriate***		1.Industrial concentrates 2 Mineral Licks 3.Fodder crops 4.Crop residue 5. Hay 6.Silage 7. Others (Specify) ***Fill the code(s) above in the spaces below as appropriate***		1. During Milking 2. When animal show deficiency signs. 3.When there is scarcity of feeds 4. When there is social obligations. 5. Others ***Fill the code(s) above in the spaces below as appropriate***	***Fill in the Value in the space provided below as appropriate**		***Fill in the Value in the space provided below as appropriate**	
K 1 ***Tick the Choice(s) as appropriate***	K 2		K3		K4	K5		K6	
	K2-i	K2-ii	K3-i	K3-ii		K5- i	K5-ii	K6-i	K6-ii
	Wet	Dry	Wet	Dry		Wet	Dry	Wet	Dry
1.Grazing						______	______	______	______
2.Stall- grazing						______	______	______	______
3.Tethering						______	______	______	______
4. Others (Specify)						______	______	______	______
						______	______	______	______

K7. What are major constraints to feeding programme of your dairy enterprise

i_________________________ii_________________________iii_______________________________

K8. Is i) Hay making done 1. Yes 2. No

ii). Silage making done 1. Yes 2. No

K9.If hay making is done, when did you start the hay making in the farm?

1. Before 2010 2. Year 2010 3. Year 2011 4.Year 2012 5. Others (Specify)

K10i. If hay making is done, what is the method of hay baling is used 1.Hay boxes 2. Hay Baler 3. Others

K10ii. How many number of bales are obtained per acre?___

K11i.If silage making is done what is the method used in making the silage:K11ii How much silage is obtained per acre________

1. Silo/Trench 2. Polythene / Plastic Bags 3. Others (Specify)

K12.i).List the problems associated with Hay making 1.____________________2.________________3.____________

ii). List the problems associated with Silage making 1.____________________2.________________3.____________

K13. i). What of Type of feeding the dairy cattle do you use?

1. Grazing 2. Stall- feeding 3. Tethering 4. others

ii) If stall-feeding is used, state the type of feeding unit used

iii) Zero-grazing unit 2. Feeding Slab 3.Wooden Feeding Trough 4.others(Specify)

K14. If Zero-Grazing unit is used, state the components that have been installed.

1. Milking Parlour 2. Feed Trough 3.Water Trough 4. Calf Pen 5.Store 6. Exercise area

K14. How often is the Zero-grazing unit cleaned?

1. Every day 2. Every 2 days 3. Every week 4. Every two week 5. Others(Specify)

K15. State the main problems associated with the zero-grazing unit

1. Poor drainage 2.Bad smell 3. Inadequate space 4. Broken Parts/Damage 5.Others(Specify)

L: FEED UTILIZATION IMPROVEMENT TECHNIQUES

L1. What are the techniques you use to improve utilization of the feedstuff

1. Chopping of feedstuff 2. Addition of Molasses 3. Cut and Carry Method 4. Paddocking of Pastures

5. Formulation of feed mixture 6.Others (Specify)

L2. i).Do you use Hay Barn to store excess forage or prepared hay or silage? 1. Yes 2. No

ii). If no, which other structures do you store your excess forage or prepared feedstuffs

1. On trees 2. Granary 3. Gunny bags 4. Others (specify).

L3. i) Is chopping of forage done 1. Yes 2. No

ii). If Chopping of feedstuff is done, what equipments are used

1. Panga 2. Fixed Knife Chopper 3.Industrial Chaff-cutter. 4.Pulverizer 5. Others(Specify)

L4. Rank the three (3) most important equipment used in your farm to increase feed utilization

i.____

ii.____

iii.____

L5. What are the main constraints to better utilization of the feedstuff.

1. Expensive equipment 2. Expensive Labour 3.Lack of Skills 4.Lack of capital 5.others(Specify)

L6. Rank the three (3) major constraints hindering better utilization of the feedstuff

i.____

ii.____

iii.____

L6.i) Do you use crop residue(s) to feed your dairy cattle? 1 Yes 2 No

ii). If yes, what type of crop residue(s) are used commonly

1. Maize stover 2. Legume residue 3. Rice/Wheat bran 4. Others (Specify)

M. WATER HARVESTING AND UTILIZATION TECHNIQUES

M1. What are the water sources to your farm?

1. Piped water 2. Rivers 3.Earth dams 4. Surface Ponds 5.Boreholes 6.Sand dams

7. Others (Specify)

M2. Rank the three (3) major sources of water

a) Wet season. i.____________________ii.________________________iii________________________

b) Dry season. i.____________________ii.________________________iii.________________________

M3. State the constraints of water supply to your farm

1. Drought 2.Inadequate storage 3.Poor Harvesting 4.Inefficient methods of utilization 5.others(Specify)

M4. Rank the three (3) major constraints in the farm

i.______________________ii__________________________iii.____________________________

M5. i). Is water harvesting done in 1 . Yes 2. No

ii). What are the surfaces do you use for water harvesting techniques in your farm? State when water harvesting started______________________(Indicate the period in years)

1. Rooftop surfaces 2. Rock surfaces 3. Bare surfaces 4. Road sides 5. Plastic/Polythene Sheets

6. Others (specify)

M6. Rank the three commonly used surfaces in your farm

i.____________________ii__________________________iii_________________________________

M7. State ways used to store harvested water

1. Concrete Tanks 2. Plastic Tanks 3. Earth dam 4. Surface Pond 5. Others (specify)

M8. Rank the 3 most commonly used method of storage

I_____________________ii__________________________iii_____________________________

M9. What are ways in which harvested water is utilized in your farm?

1. Domestic 2. Irrigation 3. Watering of Animals 4. Construction 5. Others(Specify)

M10. If irrigation is done state the common crops that are irrigated

1. Food Crops-Maize/beans 2. Vegetables 3. Fruits 4. Fodder crops 5.Others

M11. What is the acreage of the three (3) main crops irrigated in your farm?

I._crop _____________Acre________ii .Crop_________acre ________iii. Crop______Acre______________

M12. What is the type of irrigation system is used to irrigate the above mentioned items?

1. Drip Irrigation 2.Bucket Irrigation 3. Sprinkler Irrigation 4. Basin Irrigation

5. Furrow Irrigation 6.Others (specify)

M13. State the main constraints for the use of the irrigation in your farm

1. Lack of equipments 2.inadequate supply 3.Lack of Labour 4.Poor Terrain

5.High evaporation 6 Others (Specify)

M14. Rank the three (3) main constraints in the irrigation in your farm

I____________________ ii.___________________ iii__________________

M15. What is the type of equipment used for the irrigation purposes in your farm?

1. Sprinkler 2.Drip- Kit 3.Hose pipe 4. Buckets

5. Watering Cans 6. Others (Specify)

M16. State the order of the 3 main equipments commonly used for the irrigation

i.______________________ii_________________________iii_____________________

M17. State ways those are likely to increase the efficiency of the irrigation system?

I_______________________ii_________________________iii______________________

N: MILK PRODUCTION, MARKETING AND VALUE ADDITION TECHNIQUES

N1. i). Do you belong to a co-operative society? 1. Yes 2. No

ii). Which other farmer group organizations /movement do you belong to?

1. .Farmer self- Help group 2 . Others (specify)

iii). When did you join?____________________

N2. What are the activities of the farmer group organization/ movement do you benefit from?

1. . Sourcing of inputs 2.Marketing of milk

3. Value addition of milk. 4. Extension Services 5.Collaboration ` 6. Credit to farmers

N3.i). What is the state of your access to credit? 1. Yes 2. No

ii).Where do you get credit facilities to improve your operational capital

1. .Commercial Banks 2. Micro-financial institution 3. Other farming activities

4. Other Non-farming activities 5 Co-operative society 6. Others (Specify)

N4.How are proceeds of the Farmer group organization / movement shared?

1. Dividend to members 2.Payment for Milk delivered 3.

N4. How many cows are you milking in your farm?

1. None 2. One 3.Two 4. Three 5. Four 6. Five

7. Six 8. Others (Specify)

N5. What is the milk yield per cow

Serial No. of Cow	**Milk Yield perDay/cow (Morning+Evening)**
N5-i	N5-ii
1	
2	
3	
4	
5	
6	
Grand Total Milk Yield/Day	

N6. What was the average milk yield per cow in:

i. 2010_____________________________ii. 2011_____________________________iii. 2012________________

N7. What is average milk consumption for the household in i.2010______________________________ii 2011___________________iii.2012_________________________

N8. What are the market outlets for your milk produced in the farm?

2010 *Tick the Choice(s) as appropriate*	Milk Prices (Kshs/Litre) ***Fill in the Value in the space provided below as appropriate**		2012 *Tick the Choice(s) as appropriate*	Milk Prices (Kshs/Litre) ***Fill in the Value in the space provided below as appropriate**	
	Wet Season	Dry Season		Wet Season	Dry Season
N8-i	N8-iia	N8-iib	N8 –iii	N8- iv a	N8-ivb
1.Neighbour 2.Milk Vendors 3.Catering unit(Hotels) 4.Co-operative Society 5.Institution 6.Others(Specify)	__________ __________ __________ __________ __________ __________	__________ __________ __________ __________ __________ __________	1.Neighbour 2.Milk Vendors 3.Catering unit(Hotels) 4.Co-operative Society 5.Institution 6.Others(Specify	__________ __________ __________ __________ __________ __________	__________ __________ __________ __________ __________ __________

N9. State the main constraints in milk marketing in the area?

1. Poor prices 2. Milk Spoilage 3. Lack of market 4.Poor infrastructure

5. Unfair competition 6.Corruption 7. Mismanagement 8.Non-payment 9.Delays in Payment

10. Others (Specify).

N10. Rank the three (3) main constraints affecting the milk

i.______________________ii_________________________________iii______________________________

N11. i). Do you carry out milk value addition process in your farm? 1. Yes 2. No

ii).Which milk value addition processes do you carry out in your farm?

1. Milk fermentation 2. Yoghurt production 3.others(specify)

N12. What equipments do have for milk handling and storage

1. Strip Cup 2. Milking buckets 3. Milking Cans. 4. Others (Specify)

N14. How does the prices of the milk product(s) compare after the milk value addition?

1. Below 2. Same 3. High.

O: EXTENSION SERVICES / INFORMATION SOURCES IN DAIRY ENTERPRISE:

What are Sources of Information	What are the Channels used for dissemination of Technologies	Which Areas/Sections of innovations are included during dissemination	What is the Frequency of the Dissemination of Technology(Fill in the Blank spaces)
O 1 ****Tick the Choice(s) as appropriate***	**O 2** ****Tick the Choice(s) as appropriate***	**O 3** ****Tick the Choice(s) as appropriate***	**O 4** ***Fill in the Value in the space provided below as appropriate**
1.Government officer	1. Field Days	1.Pasture/Fodder management	_____________
2.Research Centres	2. Visits to Source	2.Feed utilization	_____________
3.NGOs	3. Seminars	3.Feed Conservation	_____________
4.CBOs	4. Workshops	4.Feed Preservation	_____________
5.Other Farmer	5. Conferences	5.Water harvesting	_____________
6.Agro- Vets	6. ASK Shows	6.Water Conservation	_____________
7.Manufacturers	7. Others(Specify)	7. Health Care	_____________
8.Private Practitioner		8. Milk handling and preservation	_____________
9.Radio		9.Milk Value Addition	_____________
10.Newspapers			
11.Tvs Shows			
12.Others(Specify)			

O5. i). How is your access to extension? 1. Good 2. Poor

ii). Rank the major sections in which technologies are disseminated to you

i___________________________________ii_______________________________iii___________________________________

O6.State the major constraints in the dissemination of technology in the Dairy sector

i____

ii____

iii____