Modelling GHG Emission, Cost and Benefit Analysis within the Dairy Farming System. A case study of Githunguri Dairy Farmers Cooperative Society Ltd and Olenguruone Dairy Farmers Cooperative Society Ltd, Kenya

VALA ANASTASIA

Van Hall Larenstein University of Applied Sciences

The Netherlands

September 2019

Modelling GHG Emissions and Cost and Benefit Analysis Within the Dairy Farming Systems: A Case Study of Githunguri Dairy Farmers Cooperative Society Ltd and Olenguruone Dairy Farmers Cooperative Society Ltd, Kenya

Research Submitted to Van Hall Larenstein University of Applied Sciences in Partial Fulfilment of the Requirements for Degree of Masters in Agricultural Production Chain Management, Livestock Chains Specialization.

By:

VALA ANASTASIA

Supervised by:

Marco Verschuur

Examined by:

Robert Baars

The Research is part of the ``Climate-Smart Dairy Project in Ethiopia and Kenya'' and of the Professorship `` Dairy Value chains'' and `` Sustainable Agribusiness in the Metropolitan Areas''

September 2019

Van Hall Larenstein University of Applied Sciences, Velp.

The Netherlands

Permission to use

In bestowing this Research Project as a Partial fulfilment for the requirements of a Master's degree in Agricultural Production Chains (APCM), Livestock chains specialisation, I do approve that, VHL University of Applied Sciences will make it accessible in whatever manner for assessment. I further agree that consent for copying or publication of this research project in whole or part for academic purposes is approved by the Director research VHL University of Applied Sciences in the Netherlands. Publication, copying or any other use of the research for monetary gain shall not be permissible without my approval. Any use of this research report for academic purposes shall give due credit to me and the university.

Request for consent to use the report should be addressed to:

Director of research, VHL university of applied Sciences,

P.O Box 9001

6880 GB Velp

The Netherlands

ACKNOWLEDGEMENTS

First, I Acknowledge the Almighty God for giving me life, good health and strength during the entire period. His sufficient grace kept me far away from home.

I am appreciative to the Government of the Kingdom of the Netherlands through the NFP (Netherlands Fellowship Programme) for offering me a scholarship to pursue a postgraduate degree programme in Masters Agricultural Production chains (livestock chains) at Van Hall Larenstein University of Applied Sciences. without your financial support, my master's programme would have been impossible. Gratitude to NOW- CCAFs for funding my research.

I would like to thank Mr. Musembi State department of Livestock Production Kenya, Training department for your advice to pursue a master's programme at Van Hall Larenstein university of applied sciences.

Special thanks to Mr. Marco Verschuur, my supervisor and course coordinator livestock production chains for his unwavering support, guidance during my study period and in preparation of the thesis. Mr. Robert Baars for your criticism and extroverted feedback during the research process.

I would also like to thank the entire staff of Van hall Larenstein University of Applied sciences for the valuable support extended during the entire study period. The learning experience was overwhelming and exceeded my expectation.

I would like to thank the quality Assurance and extension Department Githunguri Dairy farmer's cooperative society headed by Mr. Francis Muhande and his deputy Mr. Andrew Kariuki for their support during the data collection period. Mr. Mburu, DEO GDFCS, your immense and tireless efforts of linking me with dairy farmers in Githunguri sub-county. I am also grateful to Mr. Sammy SCLPO Kuresoi South Sub-county, Nakuru county for linking me with Olenguruone Farmers' Cooperative society management and also Olenguruone farmers which enabled me to collect data in Olenguruone.

Last but not least, I am grateful to all the farmers of Githunguri Dairy Farmers Cooperative and Olenguruone Dairy Farmers Cooperative for allowing me in their farms and willingly supplying me with information that has been used in compiling this report.

Dedication

I dedicate this research to the Almighty God for his grace and divine strength throughout the entire study period. My wonderful parents Benedicto and Tabitha Vala for your support, prayers and encouragement. My brothers Patrick, Joseph, Stephen and Samson Vala your love and concern while I was away encouraged me to soldier on. Lastly to my friend's Blessings, Florence and Robert for your encouragement and moral support. God bless you all.

CONTENTS

List of tables

List of figures

ACRONYMS

CCAFS	Climate Change Agriculture and Food Security
CBA	Cost-Benefit Analysis
CSA	Climate-Smart Agriculture
CSDEK	Climate-Smart Dairy Ethiopia and Kenya
CO_2.eq	Carbon dioxide equivalent
CH4	Methane
DEO	Dairy extension Officer
DFS	Dairy Farming Systems
FPCM	Fat and Protein Corrected Milk
GDFCS	Githunguri Dairy Farmers Cooperative Society.
GHG	Green House Gases
GCP	Global Challenges Programme
GLEAM	Global Livestock Environmental Assessment Model
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Analysis
MOALF	Ministry of Agriculture Livestock and Fisheries
MOENR	Ministry of Environment and Natural Resources
Mt	Metric Tonnes
NH_4	Ammonia
NO_2	Nitrous Oxide
NWO	Netherlands Organisation for Scientific Research
OLDFCS	Olenguruone Dairy Farmers Cooperative Society
SCLPO	Sub-county Livestock Production Officer
TLBCM	Tripple Layer Business Canvas Model

ABSTRACT

Understanding the effects of GHG emissions, cost and benefit analysis within the dairy farming system has become an important concern with respect to food security. The main objective of this study was to evaluate the impact of climate-smart practices in the dairy farming systems centred on economic and environmental cost (GHG) emission and benefit analysis to advice the VHL (Van Hall Larenstein) consortium for the enhancement of scalable dairy farming systems on the inclusive and resilient business model. The study was conducted for farmers of Githunguri and Olenguruone dairy farmer's cooperative society in Kenya. Purposive random sampling was done to identify 3 farmers in Githunguri,1 in Limuru and 2 in Olenguruone. Attributional LCA (life cycle analysis) was used to quantify the environmental impact upstream (feed transport and processing), downstream (dairy herd, feed, manure management and on-farm feed production). Results show that milk production had 7.58 Kg CO_2 per litre, manure 0.126 Kg CO_2, feed production 0.000053 Kg CO_2 and feed transport 0.10545 Kg CO_2. The carbon foot prints for the 6 farms when milk was allocated to other functions in dairy was 1.26 Kg CO_2eq./kg of milk, 2.87 Kg CO_2 eq.,1.87 Kg CO_2 eq, 1.30 Kg CO_2eq./kg, 1.41 Kg CO_2 eq./Kg and 0.42 CO_2 eq. The cost-benefit analysis of the climate-smart practices biogas production, water harvesting and solar panel show that farmers with climate-smart practices had an average net result per cow with CSA of Kshs. 49,127 while without CSA Kshs 41,275. Milk production, livestock category feed type and quality can vary enteric fermentation in a farm hence CH_4. Therefore, farmers increasing their milk production and checking the type and quality of feed fed to the animal can lead to a reduction of GHG emissions in the farm. The adoption of climate-smart practices is not only a GHG reduction strategy on the farm but also a cost-benefit item.

Keywords: GHG, cost and benefit analysis, climate-smart practice

CHAPTER ONE: INTRODUCTION

1.1 Background information on climate change

Climate change is real challenging all nations to acclimatize to the changing climatic conditions as well as contributing to their mitigation. It is having substantial effects on ecosystems and natural resources upon which the livestock sector depends. The change is affecting the sector directly through increased temperature, changes in the amount of rainfall and shifts in precipitation patterns. Indirectly, there are modifications in ecosystems, changes in the yields, quality and type of feed crops, possible increases in animal diseases and increased competition for resources. Similarly, livestock food chains are a major contributor to Greenhouse gas (GHG) emissions ((FAO, 2013). The GHG emissions from the livestock sector are primarily comprised of methane (44%), nitrous oxide (29%) and carbon dioxide (27%). Enteric fermentation which is a natural part of the digestive process for many ruminant animal's accounts for 39% of livestock sector emissions. Feed production and processing 45%, manure storage 10% while the remaining 6% is from the processing and transport of livestock products (Gerber, et al., 2013).

Agriculture in Kenya is mainly rain-fed and dominated by small scale farmers in the medium to high potential and semi-arid areas. It contributes to over 25% to the GDP, 65% of the total exports and provides more than 18% of formal employment. The Greenhouse gas (GHG) emissions from agriculture are estimated at 20 $MtCO_2$ in 2010, expected to rise to 27 $MtCO_2$ by 2030 (Solomon, et al., 2017). The livestock sub-sector contributes to 90% of the emissions mainly from enteric fermentation. Extensive livestock farming systems, clearing of forests and grasslands to open up land for grazing, low quality and low digestible feeds and poor animal health and husbandry all contribute to high GHG emissions ((MOALF & MOENR, 2017). Land preparation, fertilizer use during pasture establishment, processing of inputs, poor manure management, processing of produce and transportation are also sources of emission in the sector.

Climate-smart agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support the development and ensure food security in a changing climate. CSA contributes to the achievement of sustainable development goals by integrating three dimensions of sustainable development, economic, social and environmental, jointly addressing food security and climate challenges (MoALF & MoENR, 2017).

1.2 Overview of the dairy sector in Kenya

Kenya has a vibrant dairy sector that is private driven and the single largest sub-sector of agriculture. It contributes to 14% of Agricultural GDP and accounts for 6-8% of the country's GDP. It is a significant source of livelihood to approximately 1 million small scale farmers and the most expanding subsector in Sub-Sahara Africa with 85% of the dairy cattle population in East Africa (Waitituh, 2017). It provides income and employment to nearly 2 million people across the dairy value chain. It is also a source of food and nutrition with per capita consumption of 115 litres. The demand for dairy products is expected to continue growing rapidly as a result of population growth (FAO & Newzealand Agricultural Greenhouse Research centre, 2017).

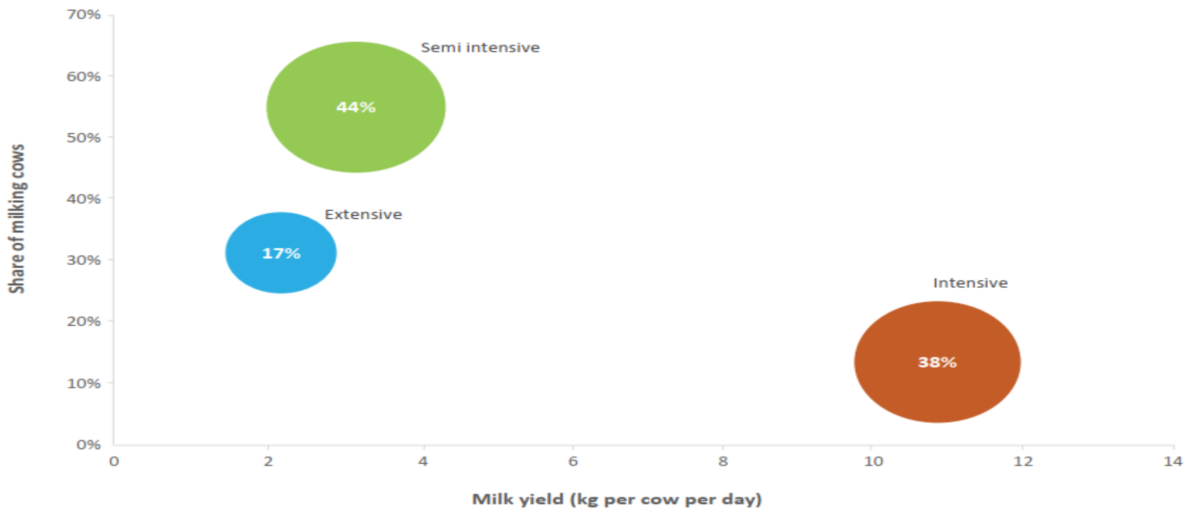
There are about 25 milk processing plants licensed by the Kenya Dairy Board in Kenya with a processing capacity of 3.5 million litres per day. They have a capacity utilisation of 40-50 which is low due to the seasonality of production and competition from the informal sector. The market for processed milk is dominated by Brookside Dairy Ltd. New Kenya Cooperative Creameries Ltd., Githunguri Dairy Cooperative Society and Sameer Agriculture and Livestock Ltd. They jointly account for 70% of the processed milk market and 21% of the Kenya total milk market with other processors accounting for 30% of the remaining market segment((MOALF, 2017). The growth and competitiveness of the dairy industry are constrained by seasonality in milk production, milk quality issues, lack of knowledge and skills, substandard service provision and input supply and lack of inclusive business models. If the issues are effectively addressed, this will promote commercialization and growth of the sector, contribute further to the creation of wealth, employment across the value chain and to food security (Ettema, 2013).

Dairy farming is concentrated in the high altitude agro-ecological zones of the central highlands and Rift valley regions with a high and bimodal rainfall and relatively low temperatures between 15^{o}C and 24^{o}C. More than three- quarters of the households in the two regions engage in agriculture with 73 % practicing integrated farming((Kashangaki & Ericksen, 2018). The main dairy producing breeds are Friesian, Guernsey, Ayrshire, Jersey and their crosses kept under intensive and semi-intensive production systems. The distinction between the production systems is based on size, level of management and use of inputs.

1.3 Green House Emission(GHG) in the Kenyan Dairy sector

The dairy cattle population in Kenya is estimated to be 4.3 million producing 3.4 billion litres of milk. The largest share of milk production is from the semi-intensive dairy cattle production system which contributes to 44 % of total milk supply from 55% of the milking cows. The intensive system contributes 38% from 14% of the milking cows while the extensive system 17% from 31% of milking cows (FAO & Newzealand Agricultural Greenhouse Research centre, 2017).

Figure 1:Milk yield and contribution to milk yield by the production system

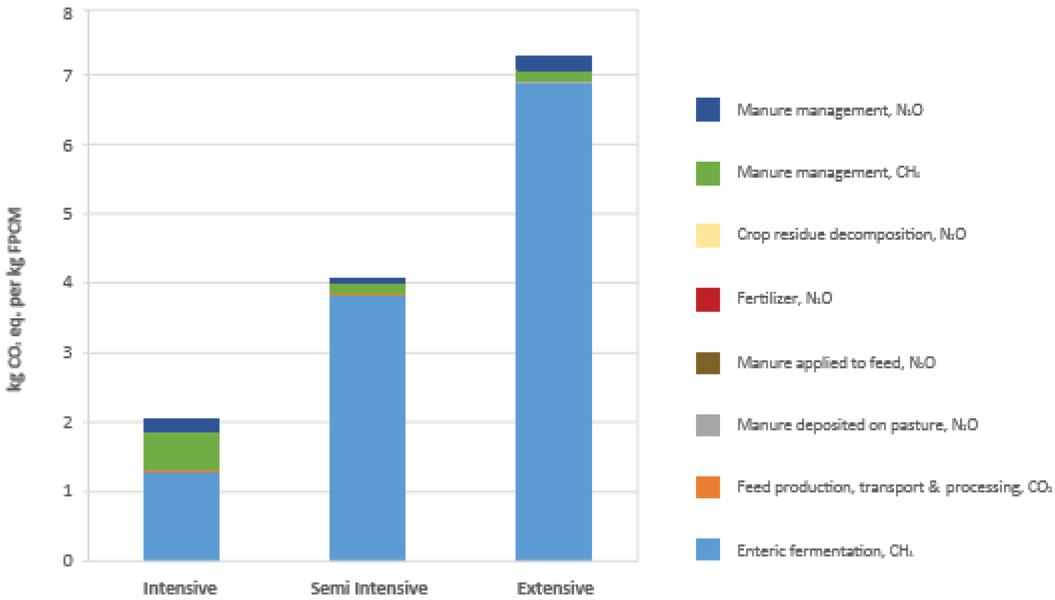


Source: FAO & New Zealand Agricultural Greenhouse Research Centre, 2017.

In reference to figure 1 that shows milk yield and contribution by the production system, Githunguri is considered to be in the intensive dairy farming system category.

In Kenya, milk production from the dairy cattle sector is responsible for about 12.1. million tonnes CO_2 eq. The activities that contribute towards GHG from the sector are enteric fermentation (CH_4), manure management and decomposition (CH_4, N_20), fertilizer application(N_2O) and feed production, transport and processing (CO_2). The GHG profile is dominated by CH_4 95.6%, N_2O 3.4 % and CO_2 1 % of the total emissions (FAO & Newzealand Agricultural Greenhouse Research centre, 2017). The emission intensity of milk produced is on average 3.8 kg CO_2 eq./kg FPCM with extensive systems producing 7.1 kg CO_2 eq./kg FPCM, intensive systems 2.1 kg CO_2 eq./kg FPCM and semi-intensive systems 4.1 kg CO_2 eq./kg FPCM (FAO & Newzealand Agricultural Greenhouse Research centre, 2017). Based on this information, intensive systems have low emission intensity of 2.1 kg CO_2eq./kg FPCM as compared to extensive and semi-intensive systems. This supports the findings of Kiiza (2018), and Shumba (2018), on upscaling climate-smart strategies in Githunguri and Ruiru sub-counties. They found out that, small scale farmers who mainly practice intensive systems of production had adopted climate-smart practices that contribute to the reduction of emission in farming systems although the adoption rates were low due high cost of implementing the technologies and lack of awareness on the same. The practices are keeping of high yielding dairy breeds(Friesian), crop rotation, manure application, water harvesting and biogas production. This attributes to low emission intensity in intensive systems of production as shown in figure 2.

Figure 2:Emission Intensity per Kg FPCM, by the production system



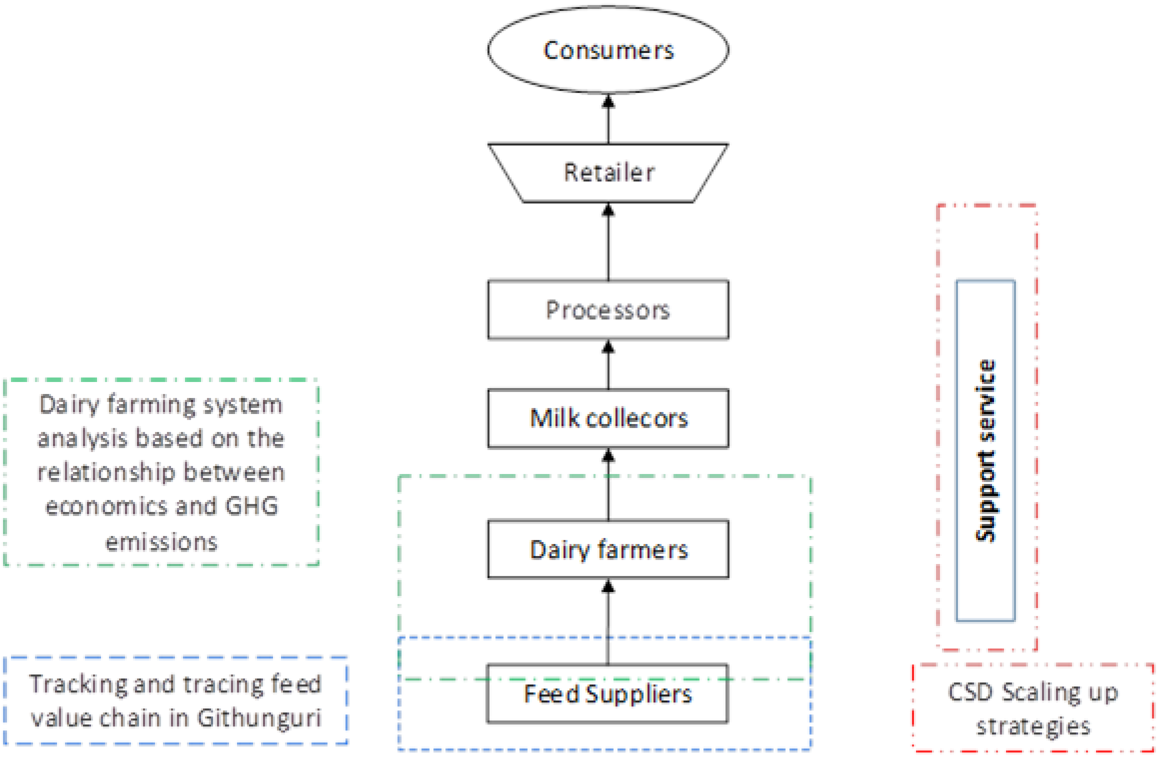
Source: FAO & New Zealand Agricultural Green House research Centre, 2017

1.4 Climate-Smart Dairy project in Kenya and Ethiopia (NWO/GCP/CCAFS)

The research project is on inclusive and climate-smart business models in Ethiopia and Kenya Dairy value chains. The project is connected to the CCAFS project titled Nationally Appropriate Mitigation Actions (NAMA) for Dairy development in Kenya. NAMA supports stakeholders in Kenya to design/pilot activities to reduce greenhouse gas emissions from dairy production. Scaling up of good practices is still lagging behind despite the many initiatives in the dairy sector. The research aims to describe business models of chain actors and supporters to identify opportunities for scaling up good climate-smart practices. Six dairy value chain case studies have been purposely selected in Kenya and Ethiopia with varying degrees of Market Orientation (Baars, 2017).

Van Hall Larenstein(VHL) University of Applied Sciences consortium as a partner to this project led a team of three CSDEK research team to Githunguri and Ruiru Sub-counties of Kiambu, Kenya in 2018 to carry out research at different levels of the Githunguri dairy value chain. The team conducted research in Scaling up mitigation practices in small holder's value chain (Kiiza , 2018), integration of climate-smart agriculture practices in feed value chains (Shumba, 2018), and integration of climate-smart agriculture in supporters of Kiambu Dairy Value chain and knowledge support systems (Wangila, 2018).   According to Wangila (2018), there exist linkages of knowledge institutions in disseminating CSA technologies/ practices led by government institutions, Research and or academic Institutions and NGOs. This creates an enabling environment for knowledge dissemination and awareness creation of mitigation strategies on climate change. Shumba (2018), found out that, dairy farmers in Githunguri are experiencing feed scarcity challenges due to land sizes. Farmers keep their dairy animals on very small plots which makes it difficult to grow fodder therefore, feeding them of poor quality fodder. This compromises the performance of the dairy animals affecting their health and production thus GHG emissions. According to Kiiza (2018), farmers in Githunguri and Ruiru sub-counties have adopted climate-smart practices such as keeping high yielding dairy breeds e.g Friesian, conservation agriculture (mulching, intercropping, cover crops), agroforestry, fodder conservation and manure management (composting and biogas). Although farmers have adopted the practices, the rate of adoption is still low due to the high cost of technologies e.g biogas installations and awareness creation. Since the aim of the project is to describe business models to chain actors and supporters, VHL consortium armed with the findings on the enabling environment in Kenya and the adoption of climate-smart practices took a step further into the research. Based on the batch 2018 inventory, CSDEK 2019 team carried out an in-depth analysis into the relationships between economics (technical) parameters and GHG emissions of average farms compared to farms with best practices and tracking and tracing of feeds in the feed value chain. The aim was to describe business models that have the economic, environmental cost and benefit component as the existing models are devoid of the component. The key focus was to have interventions that reduce emissions intensity while maintaining or increasing milk production such that climate change and productivity can be tracked together.

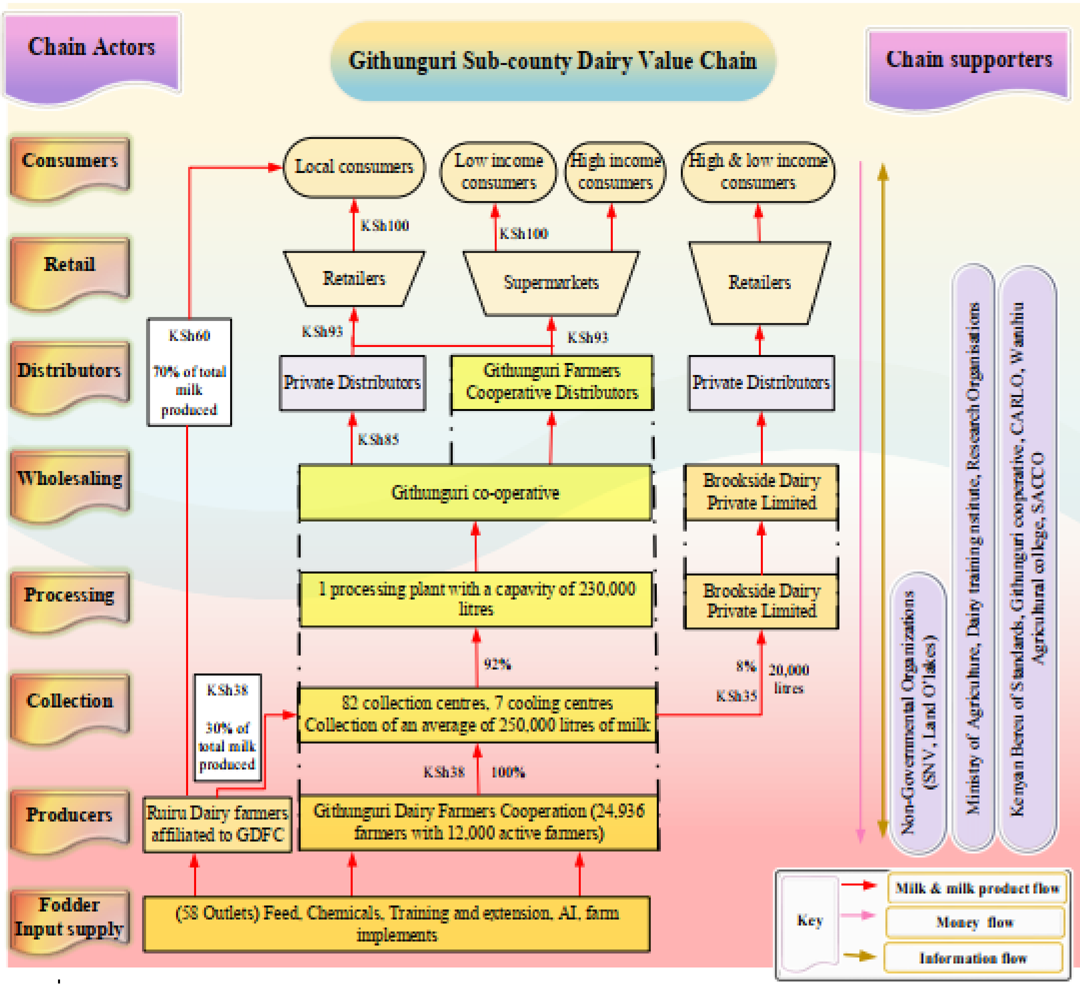
Figure 3:Project Research focus area in the Dairy value chain



Source: CSDEK 2019

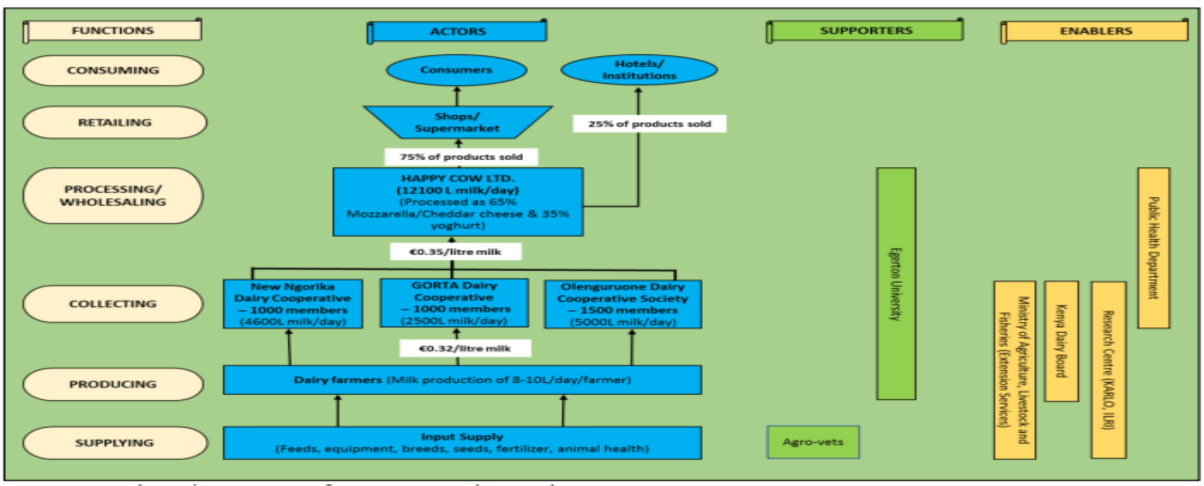
CSDEK 2018 research team carried out research in Githunguri and Ruiru sub-counties that supply milk to Githunguri Dairy cooperative society as earlier mentioned. The outcomes did not have a lot of disparities considering the fact the two sub-counties are in the same county and also having the same ecological conditions. Therefore, the study was also conducted in Nakuru county, Kuresoi sub-county and mainly to members that supply milk to Olenguruone Dairy cooperative society. Olenguruone Dairy cooperative society is one of the three cooperatives that supply milk to Happy Cow Limited a private Dutch-owned company.

Figure 4:Githunguri Dairy cooperative society dairy value chain



Source: Shumba 2018

Figure 5:Happy cow limited Kenya Dairy value chain



Source: (ugyen, et al., 2019)

1.5 Problem statement.

Although interventions for scaling up practices that support low- emission in the dairy production systems have been identified and business models developed, the in-depth analysis of economic, environmental cost and benefit component is not inclusive in the developed business models.

1.6 Research objective:

To evaluate the impact of climate Smart Practices in the dairy farming systems centred on economic and environmental, cost (GHG emissions) and benefits in order to advise the VHL consortium(Commissioner) for the enhancement of scalable dairy farming systems on inclusive and resilient business models.

1.7 Research questions

1. What are the environmental and economic costs in the dairy farming business models?
2. What are the scalable climate-smart practices in the dairy farming system?

Main question 1

What are the environmental and economic costs in the dairy farming models?

Sub-questions

1. What are the costs and revenue streams within the dairy farming systems?
2. What are the environmental and economic impacts of climate-smart practices in the dairy farming system?
3. What is the influence of seasonal feed variation on production, feed cost and GHG emissions in the dairy farming system?

Main question 2

What are the scalable climate-smart practices in the dairy farming system?

Sub-questions

1. What are the climate-smart practices within the dairy farming system?
2. What is the quantity of GHG emissions per climate-smart practice?
3. What are the level of inclusiveness and resilience in the dairy farming system and value chain?

1.8 Definition of concepts

CO_2-equivalent emission: the amount of CO_2 emissions that would cause the same time integrated radiative forcing over a given time horizon, as an emitted amount of a long-lived GHG or a mixture of GHGs. It is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon (FAO, 2010).

Enteric methane: Emissions of CH_4 from cattle as part of the digestion of feed materials (FAO & ILRI, 2016).

Fat and protein corrected milk (FPCM): Milk corrected for its fat and protein content to a standard of 4.0% fat and 3.3% protein. It's a standard used for comparing milk with different fat and protein contents (FAO, 2010).

Functional Unit: The reference unit that denotes the useful output of the production system. It has a defined quantity and quality (FAO, 2010).

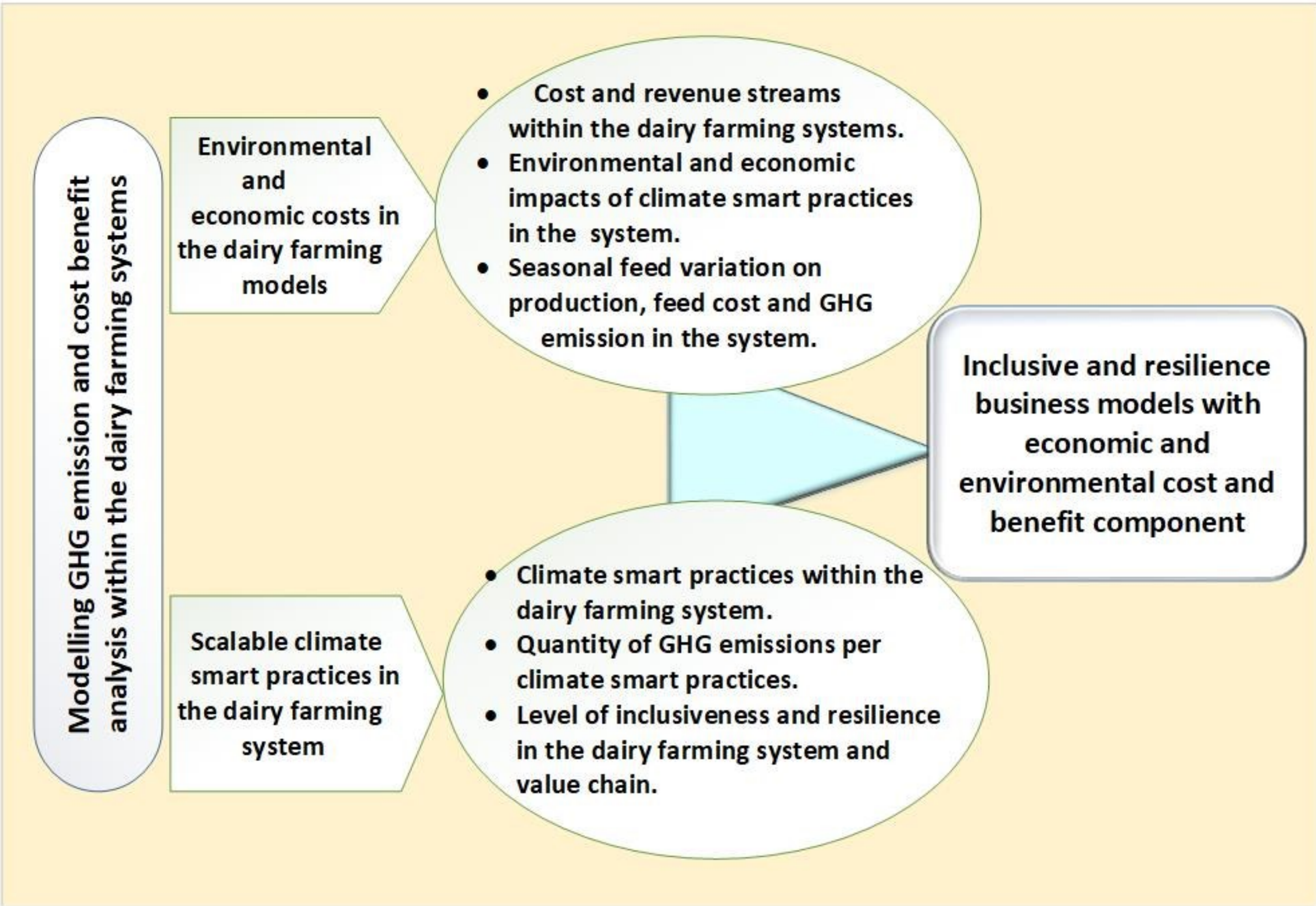
Global warming potential (GWP): An indicator that reflects the relative effect of a GHG in terms of climate change considering a fixed time period, such as 100 years, compared to the same mass of carbon dioxide (IPCC) (FAO, 2010).

Greenhouse gas: The gas that absorbs and emits radiation within the thermal infrared range.The process is the fundamental cause of the greenhouse effect. The primary greenhouse gases in the earth's atmosphere are water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) (Gerber, et al., 2013).

Smallholder farming systems: Farms raising dairy animals and producing milk where 50% of farm work is done by family members, cooperative members or neighbours (FAO & ILRI, 2016).

1.9 Conceptual framework

Figure 6:Conceptual framework



Source: Author

CHAPTER TWO:DFS, BUSINESS MODELS, CBA, IMPACTS OF LIVESTOCK ON CLIMATE, LCA AND INCLUSIVENESS AND RESILIENCE

2.1 Dairy farming systems

Dairy production is highly concentrated in the high-potential highland areas where the temperature is moderated by altitude, receive greater and more reliable rainfall than medium potential areas that are predominantly found at lower altitudes.These aspects mainly explain the present distribution of dairy farming in Kenya, as forage production is related to rainfall, disease risk is reduced at higher altitudes and market demand arose from emerging consumption centres located in the highlands((FAO & Newzealand Agricultural Greenhouse Research centre, 2017).The second-largest contributor to Agricultural GDP in Kenya is Dairy cattle production.The sector is a major source of employment in rural areas with Small scale farmers producing 80% of the total milk production. There are three well-known types of dairy production systems with intensive and semi-intensive systems comprising 85% of all the dairy farms (FAO, 2018).

Table 1:Dairy production Systems and their proportions

Dairy production system	Intensive		Semi-intensive	Extensive	
	Large scale	Small scale	(Semi-grazing)	Controlled dairy production systems	Uncontrolled dairy production systems
Proportion of farms (%)	5%	35%	45%	10%	5%

Source: FAO 2018.

2.1.1 Intensive (zero-grazing)

Zero grazing involves confinement of animals where basic housing or a simple shelter is provided with a high level of management and optimum feed.The scale of operations ranges from 1-20 cows for small scale farmers to more than 20 cows for large scale farmers. The system is dominated by small scale dairy farms estimated to make 40% of dairy production. It is predominant in Mount Kenya and Rift valley regions as crop production are practiced in these regions. It is also practiced in urban and peri-urban Centres in humid and Sub-humid areas of the country. Small scale farms keep 1- 15 dairy cows with the rural areas having an average herd size of 1-3 dairy cows while the urban areas and peri-urban areas 7-8 cows. The main breeds kept being Friesian, Ayrshires, Fleck view, Guernsey and Jersey and crosses. To maximize production, farmers use high-quality feed that is either purchased or grown on their farm. Small scale farms produce the milk mainly for the market where they sell through the cooperatives or middlemen with a small proportion used for home consumption. The intensive dairy system has a great potential for growth especially in the urban and Peri-urban areas due to the increased demand for milk and other dairy products. The system is challenged by the high cost of feeds, inadequate veterinary services to tackle major diseases, urban laws that limit livestock keeping leaving urban farmers with few possibilities for intensification and expansion (FAO, 2018).This report confirms the findings of Allen Kiiza and Honour Shumba (2018) in Githunguri and Ruiru sub-counties. Kiiza alluded that zero-grazing system is the major system in the area where animals are kept in housing units and that, majority of the farmers are smallholder farmers. Shumba established that the system is faced with the high cost of feeds, it is the major source of employment to the smallholder people of Githunguri and Ruiru sub-counties, an expansion for increased fodder production is a challenge and that the farmers supply milk to Githunguri Dairy farmers cooperative.

2.1.2 Semi-intensive (semi-grazing)

Animals are partly confined and allowed to graze freely or under paddocking and enclosed in the evening when feed supplementation is provided. The dairy cattle are raised together with chicken, sheep, goats, donkeys and intermittently pig. The system is mainly practiced in Mount Kenya, central, North Rift valley, coastal areas and areas where crop farming is practiced western and Nyanza regions. Farmers keep small herds of 1-20 dairy animals mainly crosses and exotic breeds, Friesian zebu, Ayrshire, Guernsey, Jersey, Sahiwal, Zebu and Boran. Feeding practices vary across the region which includes the use of natural grass, improved pasture and post-harvest grazing. The main diseases are East Coast Fever, anaplasmosis and mastitis as there is minimal supervision as compared to intensive systems of production. Simple structures for milking and feeding are provided whereas milk produced is largely consumed at home with about 40% of the farmers not marketing any milk. The surplus milk is sold in raw form through informal channels. Semi-intensive system is intensely constrained by seasonal variation in the pasture, water availability and limited access to A.I services constraining breed improvement and productivity (FAO, 2018).

2.1.3 Extensive system of production

It is a pasture-based production system that is dominated by exotic breeds and crosses of indigenous breeds. It exists in areas with large farms where grazing is controlled and in marginal and communal grazing lands thus uncontrolled grazing resulting in the keeping of few animals. Animals are placed on natural and improved pastures using paddocks or strip grazing and supplemented with high-quality fodder, mineral licks and commercial concentrates under controlled grazing. Uncontrolled grazing is characterised by free grazing with limited supplementation. Uncontrolled use of acaricides and dewormers increases the possibility of disease occurrence. Farm structures such as hay barns, dips, water troughs and crushes are accessible in controlled systems. Compared to intensive systems, milk production is low between 4- 11 litres per day. Although the extensive system has the largest share of the total dairy animals, seasonality in feeds availability is a challenge. Decreasing communal grazing fields as a result of increasing human settlement and development is a limitation to uncontrolled grazing. Dairy products from this system are alleged to be of high quality, organic with very low use of antibiotics, often sold in the niche and high-quality markets (FAO, 2018).

2.2 Milk production in the intensive farming systems

In addition to contributing to the sustainability of smallholder crop-dairy systems through nutrient cycling to fertilise the soil, employment creation and provision of farm household nutrition, dairying is an attractive enterprise in Kenya for income generation and food security. It supports an estimated 625,000 smallholders' producer's households. They retain 40% of the milk produced for household consumption and calf feeding while the rest is marketed via informal markets, cooperatives, self-help groups and processors (Muthui, et al., 2014). Most of Kenya dairy cattle are kept by smallholder agriculture areas of high and medium cropping potential with 80% of cattle in central and Rift valley on farms < 2 ha and an average of 1- 2 cows. Friesian or Ayrshire encompass 50% of the herd, the other half consisting of female calves and heifers. Feeding is primarily cut and carry with planted Napier grass, maize and banana crop residues supplemented by forage gathered from common properties around the farm and purchased from neighbours. The average total daily milk production is 10Kg per farm of which a quarter is for home consumption and the rest is sold (Thorpe, et al., 2000). In Kenya, smallholder dairy production systems are characterised by declining farm size, upgrading into dairy breeds and increasing dependence of purchased feeds both concentrates and forage which has led to increased milk yields per lactation. Manure is also becoming an important product in the intensive crop-dairy production systems (Thorpe, et al., 2000). Kiiza (2018), confirms the aspect of feeding wherein his findings, he stated that the animals are kept in a zero-grazing unit, feeding is cut and carry with planted Napier grass as the main source of fodder among the smallholder dairy farmers in Githunguri and Ruiru sub-counties.

2.3 Feed and Fodder

In Kenya, a small dairy farmer keeps between one and five dairy cows mostly Ayrshire, Friesian, Guernsey and Jersey crossbreds. Farmers face regular feed shortages during the dry season as Production systems are rain-fed with some producers facing year-round shortages as a result of limited land for cultivation. Feeds range from commercial concentrates to natural pasture, crop residues, green forages(weeds), leaves and pods, hay, salt and local brewery residue (Kashangaki & Ericksen, 2018). Land availability is lower in Kiambu county with most households having less than two acres however, they have higher dairy productivity of 12 kg per day than in other counties. The opportunity for fodder expansion is limited in the county and therefore, households purchase fodder to supplement concentrates dairy meal and maize germ. In Githunguri, Napier, food crop residues and desmodium are the main sources of fodder. On the other hand, in Nakuru county, landholding is two to three acres among the small scale farmers found mostly in high potential areas. (County Government of Nakuru, 2013). The average milk production is 8 litres with fodder maize and Napier grass being the main source of fodder. Oats is becoming prevalent among the dairy farmers due to its fast growth, palatability, high yielding and can be fed directly, ensiled or made to hay (MOALF, 2016). The report confirms the findings of Shumba (2018), where he found out that plot sizes in Githunguri inhibit the growth of fodder compelling farmers to purchase fodder for their animals. Better animal feeding reduces CH_4 and manure emissions resulting to higher milk yields as it infers a shift of the cow's metabolism in favour of milk production as opposed to body maintenance thus, to lower emission intensities (Gerber, et al., 2013).

2.4 Cost of feed in the dairy farming systems

The cost of milk production reflects the substitution of primary inputs.This implies that it depends on the degree of intensification with profit per litre reducing with increased intensification reflecting the amplified cost of production. The highest proportion of milk production costs are from feed and fodder. The production system, location of the farming in relation to the market, input supply, labour and land determine production costs. Income varies with the season, location, yields achieved, formal and informal milk sales and the sale of by-products such as manure. The highest cost of production is from the intensive zero-grazing system due to the high costs of factors of production. The cost of producing 1 litre of milk increases with intensification as it depends on a high level of supplementation with purchased feeds although smallholder dairy farmers have the highest returns on investment. Feeding and management make up about 80% of the total costs for a successful dairy enterprise, with feeds constituting on average 68% of the total costs (Waitituh, 2017).

2.5 Business models

A business model is a conceptual tool containing a set of objects, concepts and their relationship with the objective of expressing the business logic of a specific firm. The concepts and relationships that allow a simplified description and representation of what value is provided to customers, how it is done and with financial, therefore, be considered (Osterwalder, et al., 2005). In reference to this definition, Kiiza (2018), explains that, farmers rely on services (provision of tangible goods such as money to invest) and business services (technical advice and information) to make farming as a business. Financial institutions such as banks and microfinance institutions to offer credit along with other financial services, climate change and climate-smart agriculture-oriented institutions to offer research, training and information dissemination. Eco-friendly oriented companies like biogas companies can offer specialized services such as the installation of biogas plants (County Government of Nyandarua, 2013), and other support services in order to ensure the resilience of agricultural production systems and achieve environmental sustainability**.** Business services comprise knowledge and skills rather than objects that one can hold. In order to increase directly or indirectly the productivity of farmers resources, non-tangible services should be provided through training, demonstrations, discussions among others. The business models that service providers use when bringing services to clients are grouped into free, subsidized and fully paid (Kiiza , 2018).
A business model can also be described as a framework widely used by practitioners from start-ups to large FT Global companies to describe how a firm creates value, relates to its customers and generates revenue from a set of operations. Several elements are combined into a coherent mix that is considered to be essential for a business to be viable (Groot, et al., 2018). Value proposition (embedded value in the product/service offered to the customers), Customer segment (different type of targeted customers), Customer relationships (way the firm engages its customers), Channels (ways the customers are reached and supported),Key activities (activities essential for the business to effectively function),Key resources(physical, financial, human resources essential to function successfully, Key partners (actors that are critical to the delivery of the value proposition),Cost structure and revenue streams(key costs, revenues and market potential). According to Groot (2018), studies focusing on the adoption of CSA technologies in a

development context identify low awareness of climate change, limited understanding of what works in different agro-ecological systems and difficulties in proving the added value of CSA technologies as factors constraining adoption of CSA.The findings align with the results of Kiiza (2018), in his study he found out that, the factors that hinder the adoption of climate-smart technologies in Kiambu county were low awareness of and also the high cost of the technologies. Groot (2018), identifies value proposition as an acute issue hindering the adoption of climate technologies as it has been difficult to prove the value and demonstrate the impact of the technologies. Costs structure in the sense that the technologies are expensive and having a non –competitive returns. This also aligns with Kiiza (2018), he discussed in his findings, the high cost of technologies being a hindrance to the adoption of the technologies.The same findings are discussed by (Long, et al., 2016), as he also identifies low awareness of climate-smart technologies, high cost and lack of verified impacts of the technologies in order to convince farmers to practice them.

A Tripple layer business model canvas is a useful tool for reasonably incorporating economic, environmental and social concerns into an all-inclusive view of an organisation business model. (Joyce & Paquin, 2016). It aids to overcome hurdles to sustainability-oriented change within Organisations by innovatively conceptualizing their existing business models and communicating prospective innovations. From a sustainability viewpoint, the environmental component offers space for an organisation to clearly explore product, service and business approach innovations which may reduce negative or increase positive environment through its activities. TLBMC enables baselines to sustainability in terms of economic, environmental and social impact. It expands the economic centred approach to a standard business model by developing and integrating environmental and social canvass layers built on lifecycle (Figure 2 Annex) and stakeholders' perspectives (Figure 3 Annex) into extended business models. The expanded canvass support developing more robust and holistic perspectives on sustainability-oriented business innovation (Joyce & Paquin, 2016).

The environmental layer of the TLBCM builds on life cycle standpoint of environmental effect which is a recognised approach for assessing product or services environmental impacts transversing all stages of its life. (Joyce & Paquin, 2016).The economic canvass model (Figure 1 Annex) is used to appreciate how revenues outweigh costs. Evaluating how the organisation generates surplus environmental benefits than impacts is the core objective of the Environmental layer of the TLBMC. This allows the user to better comprehend where the Organisation's major environmental impacts lie in the business model and afford understandings to where the Organisations may Centre its attention when creating environmentally-oriented innovations. On the other hand, the social layer of the TLBMC lengthens the economic business model canvas through stakeholder approach mutual impacts amongst stakeholders and the organisation.It strives to capture the social impacts of the organisation that derives from those interactions thus providing insight for exploring techniques to innovate the Organisations actions and business model to increase its social value creation perspective (Joyce & Paquin, 2016).

Figure 7:Triple Layered business Canvass Model

<table>
<tr><th colspan="2">INFRASTRUCTURE MANAGEMENT</th><th>PRODUCT</th><th colspan="2">CUSTOMER INTERFACE</th></tr>
<tr><td rowspan="2">Key Partnerships</td><td>Key Activities</td><td rowspan="2">Value Proposition</td><td>Customer Relationships</td><td rowspan="2">Customer Segments</td></tr>
<tr><td>Key Resources</td><td>Channels</td></tr>
<tr><th colspan="5">FINANCIAL ASPECTS</th></tr>
<tr><td colspan="2">Cost Structure</td><td colspan="3">Revenue Streams</td></tr>
<tr><td colspan="2">Social and environmental costs</td><td colspan="3">Social and environmental benefits</td></tr>
</table>

Source: Osterwalder and Pigneur, 2010

2.6 Cost-benefit analysis

Cost-benefit analysis is an instrument used to define the worth of a project or strategy and assists in making decisions and evaluating existing options (Common wealth of Australia, 2006). As a quantitative analytical tool, it assists decision-makers in the effective apportionment of resources by endeavouring to measure the costs and benefits of a program or activity by transforming the available data into manageable information. In the dairy farming context, a cost-benefit analysis is important in determining the relationship between milk production costs and returns. A partial budget helps ascertain this relationship as it estimates the impact of the proposed change on the farm profits when the change affects only part of the business. This implies the change utilizes the resources already in the farm e.g cows, equipment, surplus labour.

2.7 Gross Margin and Cost prices

To detect faults in management and to compare crops, farm units, farming systems or farms over the years, gross margins are expedient (Vermerris ed, 2018). The analysis involves the examination of the variable costs and the revenue of milk sales and other farm products. Therefore, the production of goods and services by forms cannot be done when the total variable cost is higher than total revenue (Gross output) but, when

i. GM = R – TVC (Kibiego, et al., 2015).

where: GM = Gross Margin, R = Revenue, TVC = Total Variable Cost

GM = Gross output – variable costs

ii. VC = Q*P.

variable costs are costs directly related to the amount of feed produced, the quantity of milk or input costs that can be traced easily to specific farm enterprises e.g fertilizer, fodder seeds, casual labour, increase in herd value. on the other hand, fixed costs are not directly associated to the quantity of crop produced on the land reserve and have to be paid whether production occurs or not e.g land rent, land taxes, loan repayment and living expenses (Vermerris ed, 2018). Therefore, Total costs = variable costs + fixed costs.

iii. TC = VC + FC

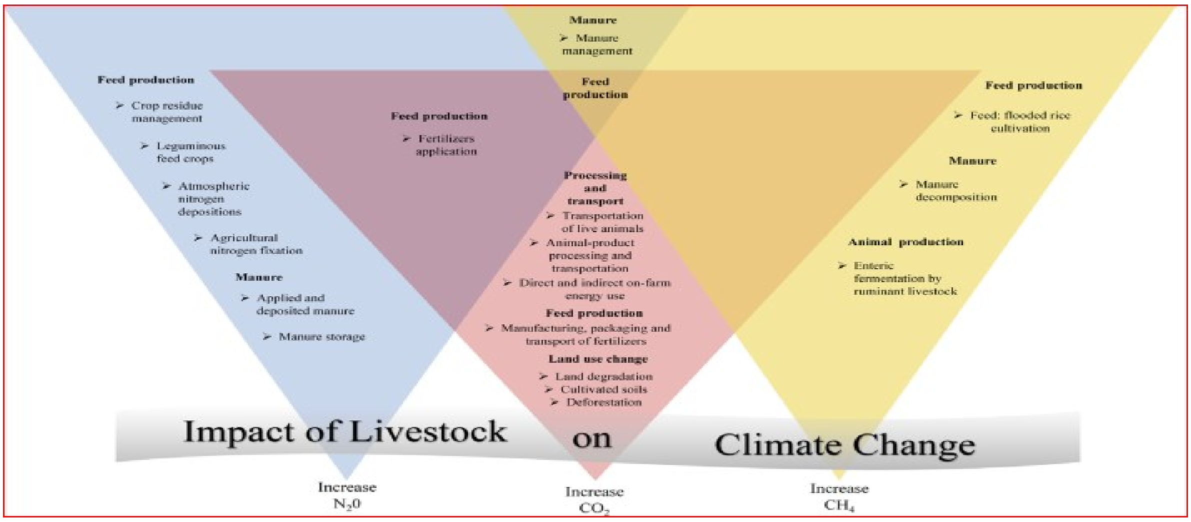
Revenues come from the sale of crops, animals and animal products (milk and manure sales and growth, etc). Thus, the gross margin derived by a smallholder farm is a measure of its performance.

Therefore: Profit or loss = Gross margin – Fixed costs

2.8 Impacts of Livestock to climate change

Globally, livestock contributes 14.5% of the total GHG emissions. They influence climate through land-use change, feed production, animal production manure, and transport. Feed production and manure emit CO_2, NO_2 and CH_4 while animal production increases CH_4. On the other hand, processing and transport of animal products and land-use change increase CO2 emissions (Rojas-Downing, et al., 2017). In Kenya, around 90% of the emissions from the agriculture sector are contributed by the livestock subsector mainly from enteric fermentation. High emissions in the sector are also due to the availability of low quality and low digestible feeds combined with poor animal health and husbandry. On the other hand, land preparation and fertiliser use during pasture establishment, processing of inputs, poor management, produce processing and transportation contribute to the emission of the subsector (MoALF & MoENR, 2017).

Figure 8:Impact of Livestock on Climate change

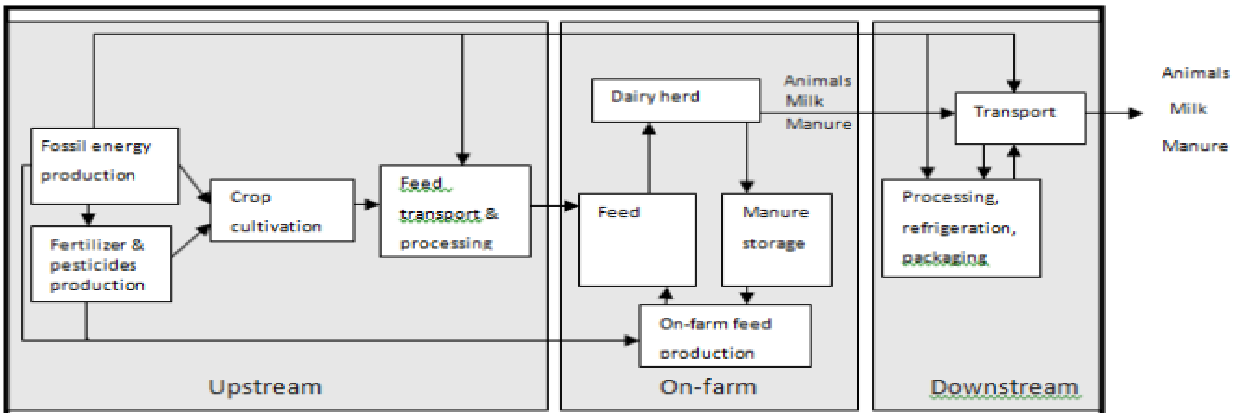


Source: (Rojas-Downing, et al., 2017)**.**

2.9 Life Cycle Assessment(LCA)

LCA involves the systemic analysis of production systems to account for all inputs and outputs associated with a specific product within a specifically defined boundary which depends chiefly on the goal of the study. A functional unit as the reference unit represents the useful output of the production system based on a defined quantity such as 1 kg of product. It is also based on an attribute of a product or process as 1 kg of fat and protein corrected milk (FPCM). LCA can be performed into two ways; consequential or attributional. Consequential LCA aims at quantifying the environmental consequences of a change in a production system or a change in product demand. On the other hand, Attributional LCA aims at quantifying the environmental impact of the main product of a system in a current situation (De Vries, et al., 2016). The multiple output nature of production where the major products are usually accompanied by the joint production of products complicates the application of LCA to agricultural systems.Therefore, an appropriate partitioning of environmental impacts to each product from the system according to an allocation rule based on either economic value, mass balances product balances is required (FAO, 2010).

Figure 9:Life cycle assessment



Source: (De Vries, et al., 2016).

2.9.1 Functional units

Dairy cattle production systems produce edible products meat and milk and non –edible products and services, draught power, leather manure and capital. Functional units used to report GHG emissions are kg of carbon dioxide equivalents (CO2–eq.) per kg of FPCM and carcass weight, at the farm gate. All milk is converted to FPCM with 4.0 % fat and 3.3 % protein, using the formula: FPCM (kg) = raw milk (kg) * (0.337 + 0.116 * Fat content (%) + 0.06 * Protein content (%)). (FAO, 2010).

2.9.2 System boundary

It embraces the whole production chain of cow milk from feed production to the final processing of milk and meat as well as transport to the retail sector. The cradle to retail system boundary is split into *Cradle to farm-gate* that includes all upstream processes in livestock production up to the point where the animals or products leave the farm(production of farm inputs and dairy farming) and *Farm-gate to retail* covering transport to dairy plants, dairy processing, production of packaging, and transport to the retail distributor (FAO, 2010).

2.9.3 Enteric emission

Enteric emission is the main source of emissions from livestock. Ruminants are the main contributors of CH_4 as a by-product of their enteric fermentation though, non-ruminants produce it to a smaller extent mainly during fermentation in their large intestines. Apart from being a GHG influencing climate change, CH_4 through enteric fermentation poses a problem as it also represents a loss of 2-12 % of gross dietary energy.This translates to losses in production and income to farmers. To heighten feed energy conversion rates and animal productivity a reduction of CH_4 emissions from ruminants is required (Onyango, 2017).

2.9 .4 Manure management

Livestock manure is a source of N_2O and CH_4 as a result of storage and processing. CH_4 is released from anaerobic decomposition whereas, nitrogen is released as NH_4 or N_2O. Manure is a valuable resource essential for plant growth as it comprises many vital micro and macronutrients, its application to cropland increases soil quality. Besides being used as manure, biodigesters which capture CH_4 from manure allowing it to be used as an energy source for the household. In Ethiopia and Kenya, ongoing projects are promoting the uptake of biodigesters as an alternative energy source to fuel and charcoal (Ericksen & Crane, 2018). Covering heaps over to maintain anaerobic conditions which reduce N_2O oxide and methane emissions is also another way that manure storage can be improved. According to Kiiza (2018), less than 60% of the farmers in Githunguri and Ruiru Sub-counties had adopted manure management practices such composting as and biogas production, feed conservation practices like hay and silage making. Shumba (2018), in addition, cites that in Kenya, there are projects promoting the adoption of biogas production by smallholder farmers. This confirms the report from ILRI by Ericksen and Crane (2018) of projects promoting the uptake of biodigesters and use of manure in crop and fodder production**.**

2.9.5 Emission from upstream activities (Animal feed production, Processing and Transportation)

Global processing emissions can be attained through energy costs of processing animals, products together with global livestock production from market-oriented intensive systems. The type of livestock systems small or largescale will determine energy use. Feed production such as seed, herbicides, pesticides, and machinery accounts for most of the energy used in confinement systems. Livestock products transported to retailers and feed to livestock farms contribute to GHG emissions with long-distance transport contributing largely to GHG emissions (Rojas-Downing, et al., 2017). Production of N fertilizer, application of manure and urine on pasture crops, manure storage, energy used for fertilization, field operations, drying, processing of feeds crops and fodder lead to CH_4, CO_2 and N_20 emissions (FAO, 2010).

2.9.6 Emissions related to land-use change

The natural landscape has considerably changed due to increasing demand for livestock products. Land degradation which is the deterioration of physical, chemical and biological properties of the soil is known as one of the drivers of land conversion from forest to croplands and pastures as producers deplete their soil resources and consequently explore for more suitable land. The natural carbon cycle is affected by land-use changes subsequently releasing high amounts of carbon into the atmosphere increasing GHG emissions. Forests as natural habitats sequester more carbon in soil and vegetation than croplands and pasturelands. Soil and terrestrial vegetation sequester up to 40% of global CO_2 emissions. However, pasturelands contain more carbon than croplands with cropland sequestering 6% of global CO_2. It is estimated that 1,100 to 1,600 billion tonnes of carbon are stored in soils which is double of that the vegetation. (Rojas-Downing, et al., 2017).Therefore, high amounts of carbon are released into the atmosphere when a forest is converted to cropland and pasture by logging or burning. The main source of CO_2 emissions from livestock production is deforestation, cultivated soils, and land degradation. Land-use change accounts for 9.2%, pasture expansion 6% and feeds crop expansion 3.2% (Gerber, et al., 2013). According to IPCC (2006), carbon losses or additions occur during the initial 20 years following the land-use change at a constant rate (FAO, 2010). MOALF, MOENR (2017), explains that, livestock systems in Kenya are mainly extensive with the clearing of forests and grasslands to open land for grazing leading to GHG emissions. Land Preparation, fertilizer application during pasture establishment, processing of produce and transport being also sources of emissions.

2.10 Climate-smart practices in the dairy farming system

According to Kiiza (2018) and Shumba (2018), farmers in Githunguri and Ruiru sub-counties were practicing several climate-smart technologies to be climate-smart in dairy production.

Water smartness

Use of high productive breeds, manure composting, biogas production, mulching, use of cover crops, zero-grazing and water harvesting contribute to climate-smart dairy farming in terms of decreasing the volume of water per unit of product (milk) (Kiiza , 2018). Feed intake, type of feed, the rate of weight gain physiological state and environmental temperature influence the daily water intake of dairy animals (Lardy, et al., 2008). Improved /high productive breeds are suited for intensive production systems where land is limited as they provide better returns and produce on average 6-times as much milk per year as zebu cattle as they are efficient converters of feed to milk (Ouma, et al., 2007). Covering of manure decreases gaseous emission and its dependent on the nature of the cover while biogas use reduces CH4 if the gas is properly captured and utilised (Misselbrook, et al., 2013). Mulching retains water by limiting water evaporation, prevents weed growth and enhances soil structure while cover crops prevent the soil from splashing of raindrops and too much heat from the sun (Duveskong, 2003).

Energy smartness

Kiiza (2018) alluded that, majority of the farmers in Githunguri and Ruiru use milk trolleys, wheelbarrows, bicycles or walk to deliver milk to collection Centres. They also use electrically driven chaff cutters and water pumps which indicate climate-smart practices as the practices have less emission intensity. Some of the farmers have adopted the production and use of biogas for cooking and lighting thereby capturing methane emissions as well as reducing fossil fuel use in households.

Carbon smartness

According to (Rojas-Downing, et al., 2017), pasture lands sequester 27 % and croplands 6% of global carbon. Conversion of Land from forest to pastureland might too decrease CH_4 oxidation by soil microorganisms, resulting in pasturelands acting as net sources of CH_4 when soil compaction from cattle hooves limits gas diffusion. Agroforestry, Mulching, conservation tillage, planting of sweet potatoes as cover crops contribute to increasing in above and below-ground biomass as well as enhancement of accumulation of organic matter and reduction of soil disturbance (Kiiza , 2018).

Nitrogen smartness

Application of manure and bio-slurry on crop fodder and intercropping are practices identified by Kiiza (2018) in Githunguri and Ruiru sub-counties. The practices have led to a reduction in the use of synthetic nitrogen-based fertilizers as well as N_2O emission reduction. Proper application of synthetic fertilizers in correct amounts is easily absorbed by plants thus reduced N_20 emissions. He confirms that, there is a decline in the use of synthetic fertilisers as farmers have adopted the use of manure on their farms.

Weather smartness

Kiiza (2018) identified that the modification of the local environment is achieved by the fact the farmers practice agroforestry. He also confirmed that Practices such as rainwater harvesting and storage, zero grazing, use of highly productive and drought-resistant fodder varieties, irrigation and fodder conservation (hay and silage making) consent farmers to be more prepared to mitigate climate change risks.

Knowledge smartness

Traditional techniques e.g mulching, crop rotation, intercropping and bush farrowing are practices that have been practiced since time immemorial and have led to ecosystems restoration. Their knowledge and adoption in livestock production will contribute to resilience to climate change (Kiiza , 2018).

2.11 Inclusiveness and Resilience in dairy farming systems

Inclusiveness

Inclusion is defined as a means of improving participation of disadvantaged persons in the society on the basis of age, sex, disability, race, ethnicity, origin, religion, or economic through better opportunities, access to resources, voice and respect for rights. As a concept, it can be a static and anticipated outcome measured against predefined indicators by means of standardized quantitative methods evaluating to what extent different groups are present in a particular program. It can also be a process-oriented approach that takes place between different actors in society explaining how formal and informal rules of inclusion operate (Minah, et al., 2018).

Many farmers do not create enough proceeds from agriculture to meet their basic needs and to re-invest in their farms. Policymakers need to ensure that national agricultural research systems involve farmers fully as partners in the development of appropriate agricultural practices for effective transformation that ensures increased incomes and food security and that research is geared towards addressing production challenges farmers face. Therefore, to ensure farmers have access to climate information and products such as best adapted crop varieties and livestock breeds, land, water, knowledge, inputs, insurance and credit, a farmer-centered approach is needed. To allow for increased input and output market access, rural infrastructure needs to be in place with farmer's organizations having a crucial contribution to make to the development of agriculture and rural communities (Solomon, et al., 2017). According to Shumba (2018), GDFCS links their smallholder farmers to finance through milk payment systems and also offers extension services through training. This displays the role of the cooperative in developing rural communities to allow for increased input and output. Wangila (2018), alluded that, there exists a strong relationship between the knowledge-based institution in disseminating the CSA to farmers. The inclusion of farmers in the development of the mitigation strategies will not only contribute to scaling up climate-smart technologies but also to increased production and income.

Resilience

The ability of systems, communities, households or persons to prevent, mitigate or cope with risk and recover from shock is termed as resilience (Faures, et al., 2013). A system is said to be resilient when it is less susceptible to shocks across time and can recover from them. Adaptation to capacity is vital to resilience and it embraces recovery from shocks and response to modifications in order to guarantee the plasticity of the system. Livelihood strategies of a dairy farmer are reliant on both the on the farm and off-farm activities to cope with risks associated with dairy farming. Dairy farmers can adopt several coping strategies to deal with diseases parasites and pests, feed shortage, poor genetics and reproduction, market fluctuation and accurate information sources, economic and financial situations, resources (physical assets), knowledge and skill, educational status, extension, farming experience, technology, livelihood strategies and attitude towards risk. The coping strategies employed by dairy farmers to deal with risk build their resilience. Therefore, to develop the resilience of dairy farmers further and to ensure the sustainability of dairy, dairy farmers should be aware of the capacities of resilience such as absorptive, adaptive and transformative capacity in an efficient and effective manner to deal with various risks (Abera, 2018). The interface of various dimensions and scales is crucial specifically because of the importance of coping with uncertainty (Faures, et al., 2013). In reference to the measurement of resilience, the adoption of climate-smart practices by the smallholder farmers in Githunguri and Ruiru sub-counties as stated by Kiiza and Shumba (2018), depicts their ability to mitigate, cope with risk and recover from shocks as a result of climate change.

CHAPTER THREE: METHODOLOGY.

The chapter gives detailed information about the study area, research design, and tools used during data collection and analysis. It also gives a comprehensive description of the study population and data sources for the different research questions. The main approach in this research is a case study.

3.1 Description of the Study areas.

The research study was conducted for Githunguri and Olenguruone Dairy farmer's cooperative society. For GDFCS, farmers were in Githunguri and Limuru sub-counties while for Olenguruone were in Kuresoi South Sub-county. The research study, therefore, is a comparative case study of the dairy farming systems (Intensive and semi-intensive) in these areas. The smallholder dairy farmers of Githunguri and Limuru sub-counties deliver milk to Githunguri Dairy farmers cooperative Society while those of Kuresoi South sub-county are members of Olenguruone Dairy Farmers Cooperative Society that delivers milk to Happy cow limited Kenya. The areas were purposively selected as they represent intensive and semi-intensive systems of production very well as well-organized dairy value chains (Githunguri Dairy Cooperative and Happy cow limited). APCM 2018 conducted research in Githunguri and Ruiru sub-counties whereby they identified climate-smart practices that were adopted by the farmers in these areas. However, the results in the two sub-counties were almost the same, considering the fact they are in the same county and with the same agro-ecological conditions hence, Nakuru county which has different agro-ecological conditions for better comparison. It is also pertinent to mention that, since it was a follow-up study, farms in Ruiru sub-county were to be studied also but there are not in this research. The project on inclusive and climate-smart business models is both in Ethiopia and Kenya and one of the CSDEK 2019 team was collecting data in Ethiopia on a farm using Milking machines as a climate-smart practice. To have a comparison of the two case studies in Ethiopia and Kenya, a farm using milking machine had to be considered and that and that's how the Limuru farm formed part of the study.

3.1.1 Geographical location.

Kiambu County is positioned in the central region of Kenya covering a total area of 2,543.5 Km^2 with 476.3 Km^2 under forest cover. The average land size is approximately 0.36 Ha on small scale and 69.5 on a large scale. Kiambu county population stood at 1.6 million people according to the 2009 Kenya Population and housing census and was projected to be 1.9 million people by 2018. It lies between latitudes 0^0 25'and 1^0 20'South of the Equator and Longitude 36^0 31'and 37^0 15'East. The county borders Nairobi and Kajiado Counties to the South, Machakos to the East, Murang' a to the North and North East, Nyandarua to the North West, and Nakuru to the West. The dairy industry is the leading enterprise with nearly 70% of farm families keeping an average of 2-3 cows under the zero-grazing system (County Government of Kiambu,2018, Kiiza, 2018).

Nakuru county lies within the Great Rift valley covering an area of 7,495.1 km^2. The average land size is 2-3 acres on a small scale, mainly found in high potential areas and 0.1 acres for urban landowners. According to 2009 Kenya population and housing census, the county population stood at 1,756,950 persons in 2012 and was projected to be 2 million in 2017. It is located between longitude 15^0 28',35^0 36 East and Latitude 0^0 13 and 1^0 10' south. To the west it borders Kericho and Bomet, North, Baringo and Laikipia, East Nyandarua, South West, Narok and to the South Kajiado and Kiambu (County Government of Nakuru, 2013).

3.1.2 Topography and Physical Features

Kiambu County is divided into four topographical zones; Upper Highland, Lower Highland, Upper Midland, and Lower Midland Zone. Githunguri and Limuru are found in the lower highland zone between 1,500-1,800 metres above sea level. The area is a tea and dairy zone characterized by hills, plateaus and high elevations plains. The sub-county has high-level uplands soils from volcanic rocks which are fertile making the area suitable for cash crop and food production as well as livestock rearing (County Government of Kiambu, 2018) (Kiiza, 2018).

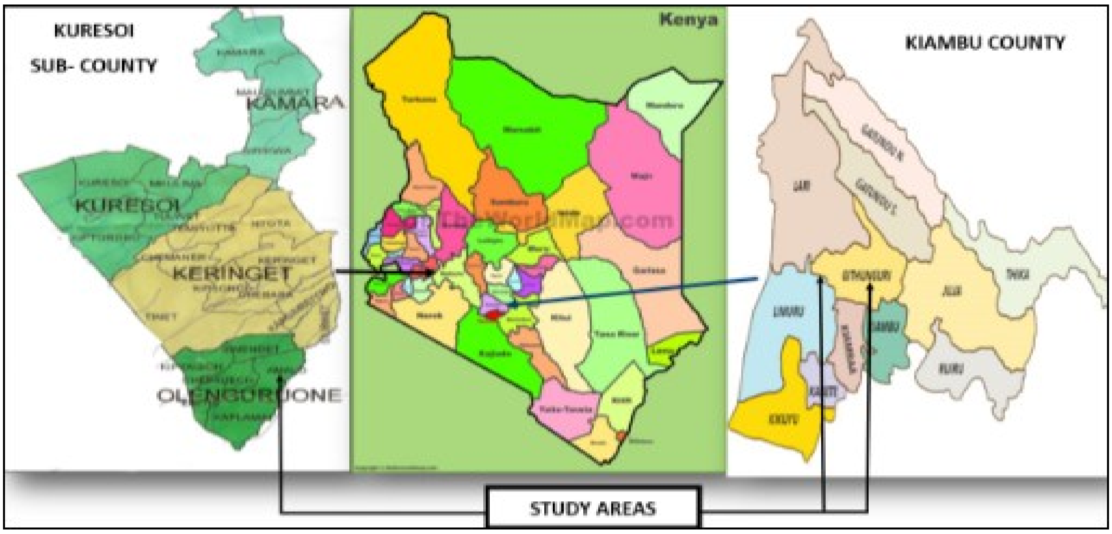
Nakuru County has 11 sub-counties, Kuresoi South being one of the sub-counties. Climatic conditions, volcanic activities and underlying rock influence the county soil pattern. Latosolic, Planosolic, alluvial and lacustrine deposits are the main soil types in the county. Olenguruone in Kuresoi South sub-county has Planosolic soils. They are considered to be fertile although, they are poorly drained dark brown clay soils with highly developed textured topsoil, well-drained humic lawns with dark brown subsoils. Sheep rearing dairy farming, wheat, barley and vegetable farming are the main agricultural activities in the area (County Government of Nakuru, 2013), (MOALF, 2016).

3.1.3 Climatic conditions

Kiambu county experiences bi-modal kind of rainfall with long rains falling between mid – March to May followed by a cold season with drizzles and frost from June to August. The average annual rainfall received by the county is 1,200 mm although, it varies with altitude with higher areas including Githunguri and Limuru receiving 2000mm and lower areas 600mm. The mean annual temperature in the county is 26^{0}c with the upper highland having 7^{0}c and the lower areas 34^{0}c. The lowest temperatures are experienced in July and August while January to March are the hottest months (County Government of Kiambu, 2018, Kiiza, 2018).

Nakuru county has a bimodal rainfall pattern with the short rains falling in October and December while the long rains fall between March and May. In the months of December, January, February and the early part of March the temperatures are 29.3 ^{0}c while in June and July they are 12^{0}c. Molo and Kuresoi South sub-counties are moderately cold likened to other sub-counties. Irregular rainfall patterns and higher temperatures owing to deforestation experienced in the county 's forest blocks and the climate change impact (County Government of Nakuru, 2013).

Figure 10:Map of Kenya showing the location of Kiambu and Nakuru county



Source: Google, 2018.

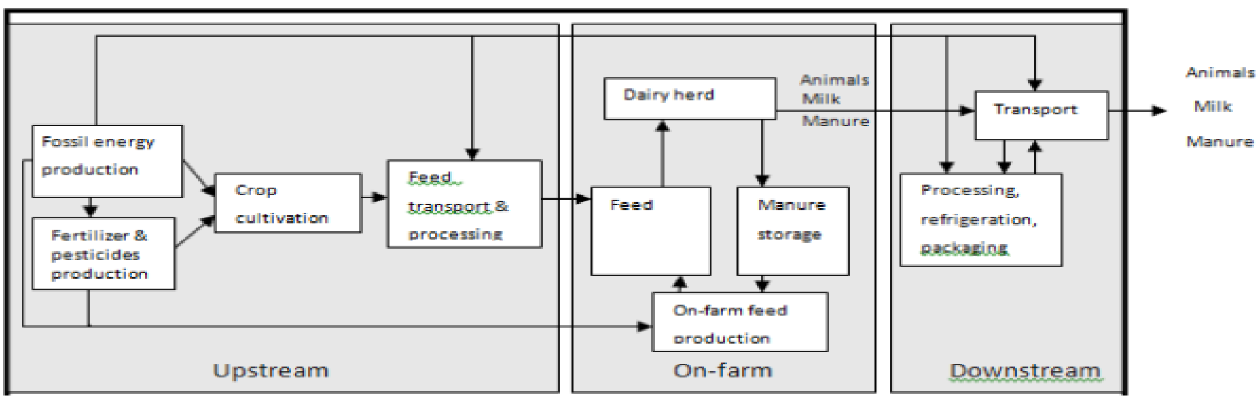
3.2 Research strategy

Qualitative and quantitative data was collected for this research.The research involved a desk study and a field study (case study). The research units in the case study were n = 6 and based on the farming systems where the smallholder farmer's household was within the farm, carrying out other activities like dairy cattle rearing, where manure is used for crop production. On the other hand, the crop residues from the crops are used to feed the animals and the output is milk production, manure and also crops. Therefore, herd composition, milk production, type of feed and quality, fodder conservation, inputs for crop production and climate-smart technologies were considered. Since the research was a follow up of the CSDEK 2018, the farms that were selected for the analysis were those practicing climate-smart dairy practices.Together with the Dairy Extension officer in GDFCS a sample size of n = 4 Kiiza (2018), alluded that some farmers in GDFCS have adopted biogas production, compost making technologies, water harvesting to be climate-smart. On the other hand, some were directly spreading and also solid drying manure on their farms. Based on the identified practices, farms were selected in order to calculate GHG emissions based on the practices in order to identify which practices can be scaled based on the reduction of gases and cost-effectiveness. Taking into account that it is a comparative study, Olenguruone Dairy Cooperative Society Ltd was not studied by CSDEK 2018, therefore to be able to identify a sample n = 2, the SCLPO Kuresoi South purposively guided in selecting farmers practising climate-smart in the area e.g fodder conservation, water harvesting, bio-digester and manure management (composting). In addition to climate-smart technology, considering dairy farming as a business and concentrating purely on the intensive system as well as practical dairy training of farmers was factored. Culture is a factor that deters women from owning cattle neither managing a dairy enterprise was considered as one of the farmers has conquered the norm and has gown ahead to manage the enterprise as the man manages another. A weighing band around the girth (girth circumference) was used to get the weights of dairy cows from different farms. During the study, the amount of milk production per day as given by the farmers was verified with the cooperatives as they had their milk records supplied for the whole year specifically for Githunguri farmers, home consumption was as they estimated. To be able to calculate the FPCM in order to get the CO_2 eq. from milk, the fat and protein content % of the two cooperatives was collected from the cooperatives. This is because the small scale farmers from the two cooperatives in spite of them keeping the same breeds, the management practices were different e.g type of feeds and also the ecological conditions. Tesfuhan (2018), GHG table developed using the IPCC (2006) standard was used to be able to account for emissions in the farms. Since the sheet was developed using feeds in Ethiopian context, to be able to use the sheets, feeds in Kenyan context and their nutrient contents were used.

3.3 Research approach

Life cycle analysis (LCA) and system boundary analysis was used to quantify greenhouse gas emission associated with the production of milk in the farms under study. Since the cradle to the retail system boundary is split into two sub-systems. *Cradle to farm- gate encompassing* all upstream processes in livestock production up to the point where the animals or products leave the farm e.g production of farm inputs, and dairy farming while *Farm-gate to retail* covers transport to dairy plants, dairy processing, production of packaging, and transport to the retail distributor. Since all aspects related to the final consumption of dairy products e.g consumer transport to purchase the product, food storage and preparation, food waste and waste handling of packaging lie external to the defined system they will be excluded.

Figure 11:System boundaries for the LCA in dairy farming systems



Source: (De Vries, et al., 2016).

Dairy production systems produce both edible goods (milk and meat) and non-edible products and services (feed, manure, draught power and capital). The products contribute to the emission of Greenhouse gases directly or indirectly. To be able to calculate the GHG emission from the products and services within the farming systems, (IPCC 2006) guidelines was used((FAO & ILRI, 2016). The emissions from the dairy farming chapter 10 Emissions from Livestock and Manure Management.The choice of the method of calculation is based on Tier 1, Tier 2 and Tier 3.

Tier 1: It involves basic characterisation for livestock populations and is sufficient for most animal species in most countries where a complete list of all livestock populations that have default emission factor values must be developed e.g dairy cow's other cattle sheep, goats.The dairy cow population is estimated separately from other cattle as dairy cows are defined as mature cows producing milk in commercial quantities for human consumption.

Tier 2: It seeks to define animals, animal productivity, diet quality and management circumstances to support a more accurate estimate of feed intake for use in estimating methane production from enteric fermentation. The feed intake estimates are used to provide harmonised estimates of manure and nitrogen excretion rates to improve the accuracy and consistency of CH_4 and N_2O emissions from manure management.

Tier 3: The approach employs the development of a sophisticated method that considers diet composition in detail, the concentration of products arising from ruminant fermentation, the seasonal disparity in animal population or feed quality and availability, and potential mitigation strategies.

N:B in reference to the definition of GWP as an indicator that reflects the relative effect of a GHG in terms of climate change considering a fixed time period, such as 100 years, compared to the same mass of CO_2 (IPCC) (FAO, 2010), the calculated emissions will converted to CO_2-eq. According to IPCC (2006), 1kg of CH_4 emitted is expressed as 25 kg of CO_2 equivalent while 1kg of N2O is 298 CO_2 eq. (FAO & ILRI, 2016). The latest IPCC (2013) Stated GWP for CH_4 of 34 CO_2-eq, while N_2O is 310 CO_2-eq. The UNFCCC (2014) stated that CH_4 emissions have a warming potential of 21 CO_2-eq, and N_2O is 310 CO_2-eq over a 100-year time horizon (Rojas-Downing, et al., 2017). For this study, UNFCC (2014) standards were used for the conversion of CH_4 and N_20 to CO_2 eq.

A. Determining fat and protein corrected milk (FPCM)

The equation for calculating FPCM from uncorrected milk yield data is:
The functional unit that will be used to report GHG emissions is kg of carbon dioxide equivalents (CO_2–eq.) per kg of FPCM at the farm gate. All milk will be converted to FPCM with 4.0 % fat and 3.3 % protein, using the formula((FAO, 2010)

$$FPCM_{it} = Milk_{it} \times (0.337 + 0.116 \times Milk\ fat + 0.06 \times Milk\ Protein)$$

Where:
FPCMi,t = Fat and protein corrected milk yield for the i^{th} cow (kg FPCM * head-1 * year-1)
MilkI,t = Total uncorrected milk production for the ith animal (kg-1 * head-1 * year-1)
Milkfat = % fat content of milk (IPCC default value is 4.0)
Milk protein = % protein content of milk (IPCC default value is 3.3)
i = index of individual animals

B. Methane emissions from enteric fermentation

Tier 2 and 3 methods for estimating methane emission from enteric fermentation will be used because enteric methane emission is a major problem in the research areas depending on the Middle East and Africa regional characteristic given by IPCC 2006 guidelines for national greenhouse gas inventories

i. **Enteric Fermentation from a Livestock Category**

ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY
$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

Where:

Emissions = methane emissions from Enteric Fermentation, Gg CH_4 yr-1

EF(T) = emission factor for the defined livestock population, kg CH_4 head-1 yr-1 (dairy cattle 46 and other cattle (multi-purpose cows, bulls and young) 31)

N(T) = the number of head of livestock species/category T in the country T = species/category of livestock

ii. **Total Emissions from Livestock Fermentation**

$$\text{Total } CH_{4\text{Enteric}} = \sum_i E_i$$

Where:

Total CH_4Enteric = total methane emissions from Enteric Fermentation, Gg CH4 yr-1

Ei = is the emissions for the ith livestock categories and subcategories

iii. **CH_4 emission factors based on Gross energy intake**

$$EF = \left[\frac{GE \bullet \left(\frac{Y_m}{100} \right) \bullet 365}{55.65} \right]$$

Where:
EF = emission factor, kg CH_4 head-1 yr-1
GE = gross energy intake, MJ head-1 day-1
Ym = methane conversion factor, per cent of gross energy in feed converted to methane(Ym) for Dairy Cows (Cattle and Buffalo) and their young is 6.5% + 1.0%
The factor 55.65 (MJ/kg CH_4) is the energy content of methane

C. **Methane emissions from manure management**

Tier 2 and 3 of IPCC will be used to quantify the emissions

I. **CH_4 emissions from manure management**

$$CH_{4Manure} = \sum_{(T)} \frac{\left(EF_{(T)} \bullet N_{(T)} \right)}{10^6}$$

Where:

CH_4Manure = CH_4 emissions from manure management, for a defined population, Gg CH_4 yr-1

EF(T) = emission factor for the defined livestock population, kg CH_4 head-1 yr-1 (Dairy cows =46 and other cattle=31)

N(T) = the number of head of livestock species/category T in the country

T = species/category of livestock

For Kenya and Ethiopia, the emission factor by average annual temperature is 1°C

II. CH4 emission factor from manure management

$$EF_{(T)} = (VS_{(T)} \bullet 365) \bullet \left[B_{o(T)} \bullet 0.67\, kg / m^3 \bullet \sum_{S,k} \frac{MCF_{S,k}}{100} \bullet MS_{(T,S,k)} \right]$$

Where:

EF(T) = annual CH_4 emission factor for livestock category T, kg CH_4 animal-1 yr-1

VS(T) = daily volatile solid excreted for livestock category T, kg dry matter animal-1 day-1

365 = basis for calculating annual VS production, days yr-1

Bo(T) = maximum methane producing capacity for manure produced by livestock category T, m^3 CH_4 kg-1 of VS excreted

0.67 = conversion factor of m^3 CH_4 to kilograms CH_4

MCF (S, k) = methane conversion factors for each manure management system S by climate region k, % MS (T, S, k) = fraction of livestock category T's manure handled using manure management system S in climate region k, dimensionless

D. The farm as an economic unit: cost price.

I. Total output: The total value of output is called **Gross output** and the total value of all input is equal to **Total cost**. Gross output is the value of what is produced on the farm while the total Farm Gross output is the sum of the individual farm enterprises. Output includes the value of farm products sold, farm re-used on the farm, the gain in the value of livestock (herd), the value of farm produce, etc.

Total output = Gross output* Price

II. Total costs = Variable costs + Fixed costs

TC = VC + FC

III. Variable costs (costs related to the amount of commodity produced and so the number of variable inputs used e.g labour fertiliser, feed etc)

Total Variable costs = Total quantity of output * Variable cost per unit of output

VC = Q*P

IV. Fixed Costs (They have to be paid whether production occurs or not the e.g land cost of oxen, equipment, farm building fencing,). Fixed costs of a capital good are built up of depreciation costs, interest costs, maintenance costs and running costs (= variable cost).

a. Depreciation costs

$$\text{Annual cost of depreciation} = \frac{\text{new value} - \text{scrap value}}{\text{Useful life in years}}$$

b. Interest costs

$$\text{Interest cost} = \frac{\text{new value} + \text{scrap value}}{2} \times \text{rate of interest}$$

c. Maintenance costs: costs which have to be made every year to keep the capital items in good working order e.g amount spent on normal repairs
d. Running costs: Actual costs to run a tractor or lorry e.g diesel, lubricants

V. Gross margin
Gross Margin = Gross output – Variable costs

VI. Profit or loss
Gross margin – fixed costs

VII. The cost price of milk
Milk production in Litres * price.

3.4 Methods of Data collection

3.4. 1 Desk research

Desk research involved reviewing relevant literature from secondary data sources such as a report, journals, books and previous thesis. The reason behind desk research was to get the concept of climate change, impacts of climate change to livestock and also livestock to climate, mitigation and adoption strategies. The information forms the basis of going further into desk research to understand what has been done in terms of scaling up strategies, challenges to adoption and the stakeholders involved. This was to help identify the gaps thus being able to come up with the research problem and research questions. Desk research was also helpful in getting information concerning different aspects that are linked to the main questions.

3.4. 2 Case study

The case study was an in-depth analysis of the Economic (technical) parameters and GHG emissions in average best-practicing dairy farms of Kiambu county and Nyandarua county. Six farm households were studied, four farms for Githunguri Dairy cooperative society and two farms for Olenguruone Dairy Cooperative Society. Basically, it was a comparative case study where farms practicing climate-smart practices were compared on the basis of the adopted practices so as to come up with a business model with the environmental cost and benefit component for the enhancement of scalable dairy farming systems on inclusive and resilient business models. It was also to make it possible for the triangulation of sources from one to one interview with the farmer, FGD, observations, and key informants. Since it was an in-depth analysis, data was collected for 3 days in each of the six farms under study.

3.4.3 Observation

A farm transect walk was conducted in the 6 farms that were purposely selected for the case study to get a clear picture of the orientation of the farm.The systematic observation was important in this study as it helped in cross-checking farmers account with what they practice e.g climate-smart practices adopted, feeding strategies, feed costs and milk production to establish the input-output relationships for gross margin analysis.

3. 4. 4 Interviews (semi-structured)

The interviews were relevant for collecting qualitative data. A checklist was developed that acted as a guide for interviews. Interviews were used alongside observation during the in-depth analysis of the farming systems. Interviews were also conducted to the key informants to gather more information on the climate-smart practices being practiced by the farmers in the area under study.

3.4.5 Focus group discussions

Two focus group discussions were held both in Olenguruone and Githunguri with men and women separately.The discussion was attended by smallholder dairy farmers of Olenguruone and Githunguri together with the Cooperative extension officers and also the sub-county livestock production officers from the county government. It was of importance to separate men and women for women to be able to open and discuss issues affecting them as in the presence of men they would not have been comfortable. Since CSDEK 2019 team were working together in these areas although, on different studies but all towards inclusive and resilient business models, the focus group discussion was held together.

A focus group discussion was critical as its action-oriented, helping to think towards a potential solution and also to get a range of experiences, opinions and in-depth information of farmer's awareness of climate change, climate-smart practices in the area, the benefits, the inclusiveness of women in climate-smart as well as the resilience aspect to climate change.

3.5 Data analysis

The data that was collected in the 6 farm case studies in Kiambu and Nakuru counties was organised, coded and an excel sheet was developed. Analysis using excel was for the purpose of getting the gross margins of the different farms. The profitability aspect was key in being able to link it with GHG gas emissions. The sustainability and adoption of climate-smart practices are tied to the 3Ps (people, profitability and Planet). Smallholder farmers must be able to achieve profit in their farming enterprises and in this way reduction in Greenhouse gases as loopholes that lead to losses will be have been identified by the gross margin analysis. Therefore, the following will be used for analysis:

LCA was used as a tool in data analysis and the Gleam model 2.1 version document (FAO, 2018) was used as a guiding checklist to ensure that all the aspects in the farm in relation to GHG emission were captured. The LCA analysis focused on the upstream and on-farm assessment of all input-output activities from cradle to farm gate. This is because the total environmental issues in the dairy value chain are at the farm level.

Economic analysis: The focus was to establish the input-output relationship in the dairy farming systems and the influence on GHG emissions per climate-smart practice implemented on the farms. The information for economic analysis was derived from the farmer's milk records and the input records for 1 year where they analysed using excel. This implies that, Gross margin, profit and loss of the farm was analysed. Besides the farm records, the researcher, was on the farm observing the other practices that the farmers were practicing and also to verify whether the information they were giving was correct.

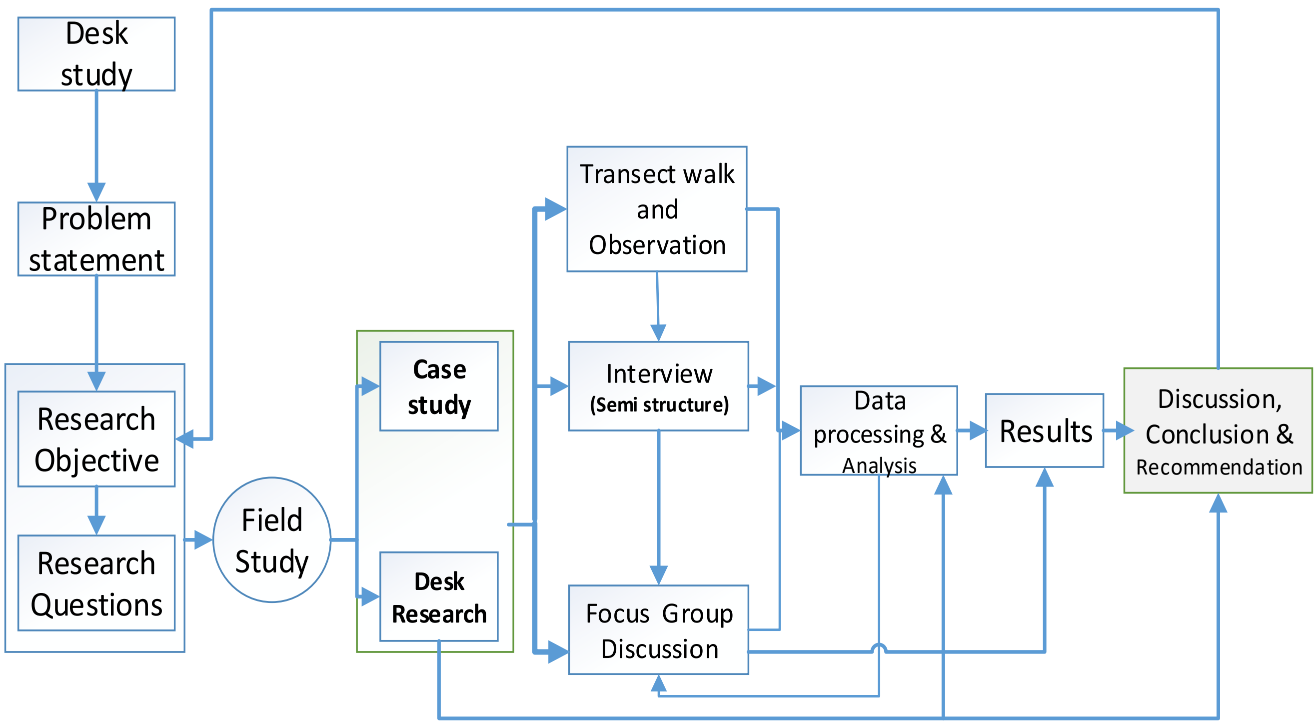
Qualitative analysis was done using the grounded theory where the information from the farmer during the farm interviews, focus group discussion and key informants were considered. The information was useful in triangulation. The key to being able to have a successful qualitative analysis was to start by transcription and compiling the information from the first farm the researcher collected data to see how effective the data was answering the research questions**.** A research framework was developed that showed the linkages between all the steps of the research and the tools and methods used in data collection to the final process of discussion, conclusions and recommendations and how each was dependent on the other. In order to know how each question was to be answered and the outcomes, a summary of the tools and methods of data analysis was also developed.

Business canvas model: Since the main objective of the study was evaluating the impact of climate Smart Practices in the dairy farming systems centred on economic and environmental, cost (GHG emissions), a business canvas model was developed based on the LCA and economic analysis to capture the Environmental cost-benefit component that has not been inclusive in the existing Business canvas models. The key aspect here was to see the influence of environmental sustainability on kg CO_2 eq of milk produced and other products in the farm and their cost-effectiveness in order to have models where climate change and profitability are tracked together.

3.6 Research framework

The research framework is a Schematic representation of the process of research from the problem identification, objectives, data collection, data analysis and finally discussion. It shows the linkages between the different data collection tools, methods of data collection and the analysis of the results of the study.

Figure 12:Research Framework



Source: Author

Table 2:Summary of tools and method of data analysis.

Research question	Source of data	Method of data analysis	What will be achieved
1.0 What are the environmental and economic costs in dairy farming models?			
1.1 What are the costs and revenue streams within the dairy farming systems?	Desk research, Observation, Interviews, Farm records	Farm system analysis,	The profitability/loss of the system Current business model
1.2 What are the environmental and economic impacts of climate-smart practices in the dairy farming system?	Desk research, Observation, Interviews, Farm case study	Farm system analysis, cost-benefit analysis Partial budget LCA	The profitability/loss of the farm Inventory of input and output GHG emissions quantification
1.3 What is the influence of seasonal feed variation on production, feed cost and GHG emissions in the dairy farming system?	Desk research Observation Interviews Farm records	Farm system analysis Farm production records LCA IPCC (2006) Tier system, GLEAM(checklist)	Seasonal calendar Feed quality and quantity Production levels, cost in relation to GHG emissions
2.0 What are the scalable climate-smart practices in the dairy farming system?			
2.1 What are the climate-smart practices within the dairy farming system?	Farm case study, observation, interview	Farm system analysis	-Inventory of climate-smart practices implemented
2.2 What is the quantity of GHG emissions per climate-smart practice?	farm system analysis, Desk study	LCA	GHG emission per Kg Co2 –eq
2.3 What is the environmental and economic impact of climate-smart practices in dairy farming systems?	farm case study – farm records interview and observation	Farm system analysis LCA Cost-benefit analysis	Environmental and economic cost per climate-smart practice
2.4 What are the level of inclusiveness and resilience in the dairy farming system and value chain?	farm case study, observation desk study, focus group discussion,	Adaptation and mitigation strategies to impacts of climate change	Triple base business canvas with a social, economic, and environmental component

Source: Author

3.7 Ethical issues

The respondents were well-versed of the objective of the research and were requested to accord permission of data collection in their respective farms.

3.8 Limitation of the study

Being an in-depth study it was required of the researcher to spend 3 days in a farm collecting data. Farmers under study are used to people carrying out survey inform of questionnaires who visit their farms for a minimum of 1 hour and they leave. For a researcher to stay collecting data in the farm for a couple of days seemed difficult to the farmers and they thought there was something more than that. The researcher had to assure the farmers that it was just data collection and nothing else. The challenge also in some farms was that, while doing an observation, the researcher could not be allowed to move around the farm without a worker as they thought that the researcher was spying their farm and collecting any other information than data collection.

Initially, the study was to cover New Ngorika Dairy Cooperative society in Ol Kalou, Nyandarua county that also supplies milk to Happy cow together with Olenguruone dairy Cooperative Society and Githunguri dairy cooperative society. I started making contacts with the livestock Production officer in Olkalou while in the Netherlands during Proposal writing who linked me to New Ngorika cooperative society through correspondence. I communicated to them but, they did not honour my request. This was a challenge because I had started collecting data in Githunguri and yet was not sure of Ngorika. I accompanied the VHL alumni and others who had attended various dairy training in different institutions who had a workshop in Kenya to visit farmers in Olenguruone. During the visit, two farmers were visited and together with the SCLPO Kuresoi South who had accompanied the team, I requested them to allow me to collect data in their farms and they agreed. This meant that I had to travel back to Githunguri, finish collecting data as I had already started and travel again to Olenguruone to collect data there.

CHAPTER FOUR: FINDINGS

The chapter presents the finding from the fieldwork. The findings are presented through graphs, tables and figures.

4.1 Farm Descriptions

The dairy farming systems during the research study were both intensive (zero-grazing system) and semi-intensive (semi zero). The intensive systems confined their animals fully while those in semi-intensive kept them in the units at night and during the day, the dairy cows were released to graze in paddocks and they would be brought to the zero-grazing unit 1 hour prior to milking to rest before they were released to the fields again. A characteristic of the farms practicing semi-intensive is that, the paddocks were not overgrazed as the animals would only stay in one paddock for a period of four days (4) before being released to another paddock. They also had a similarity in that all the paddocks had Kikuyu grass which the animals grazed on. A total of four farmers practiced zero-grazing while 2 were into semi-intensive dairy farming systems The land size for farmers in Githunguri was 1- 3 acres with an exceptional one that had 30acres while for Olenguruone 5 -12 acres. Farmers in Githunguri had small pieces of land compared to those in Limuru and Olenguruone. The farm plan was such that in the same piece of land, was the homestead, farm structures (zero-grazing, fodder stores/feed stores), vegetable gardens and fodder production as well as agroforestry. Those with small land sizes produced fodder from rented lands near their farms. Slurry from the biodigesters for those farms with biodigesters was applied in the fodder fields as well as Solid dried manure or direct application for the animals grazing in the paddocks. Nutgrass was a threat to Kikuyu grass in the paddocks. To control it, farmers ploughed the paddock completely and planted other crops like maize fodder. The farms also bought fodder e.g Hay, concentrates e.g dairy meal, wheat bran and wastes e.g brewer's yeast, pineapple waste and poultry waste while some of them prepared their homemade rations.

Table 3:Herd structure

	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6
Farming system	Intensive	Intensive	Intensive	Semi - intensive	Intensive	Semi – intensive
Herd size	66	4	5	79	18	6
Breed	Pure Holstein Friesian	Holstein Friesian Crosses	Holstein Friesian crosses	Pure Holstein Friesian	Holstein Friesian crosses	Friesian Holstein crosses
Average weight per cow (kg)	541	459	478	573	458	385
Lactating	40		1	37	7	3
Dry cows	5			7	1	
In calf in milk	12	2	3			
Heifers		1		29	4	2
Calves	9	1	1	6	6	1
Milk production	204,316.0	2,239.8	9,553.2	187,610.0	43,800.0	16,425.0
Average milk yield per cow	3929.2	1119.9	1364.7	5070.5	3981.8	5475.0

Source: Author

Table 4:Type of Feed /fodder and concentrates available in the farms.

Fodder	Concentrates	Fodder trees(Leguminous trees)	Legumes	Others
Napier grass Nandi Setaria Kikuyu grass/ improved Kikuyu grass Brachiaria Boma Rhodes(Hay) Oats Sorghum fodder Maize fodder Edible cana (fed during dry period)	Dairy meal Wheat bran Maize germ	Lucerne (Alfalfa) tree Sesbania Sesban Caliandra Grevillea Mulberry tree	Desmodium Lucerne(Alfalfa) Lupin (sweet and bitter Lupin)	Pineapple waste Brewer's yeast Poultry waste

Table 5:Homemade rations prepared by farmers

Lupin and maize flour ration	Poultry waste maize germ + wheat bran ration	Dairy 50 kg homemade ration
1 kg Lupin: 3 kg maize flour	16(debes) 10kg+ 19 bags of 50 kg maize germ + 16 bags of 45 kg wheat bran	Wheat bran 6kg Cotton seed cake 6 kg Maize germ 17.5 kg Maize grain (flour) 12.5 kg Soya bean meal /cake 2.5 kg Sunflower 5.0 kg Limestone 0.25 kg Salt (magadi) 0.33 kg **50.08 kg**
Brewer's yeast ration	Pineapple waste	
5litres H_2O + 3kg brewers waste+ 3kg Homemade ration. (fed to milking cows alone during milking)	15 kg Napier grass + 5kg pineapple waste	

Figure 13:Manure flowing along the roads

Manure management is a great challenge amongst the small farmers of Githunguri as the superfluous manure flows to the roads which is detrimental to the surroundings thus not being climate-smart. The manure if managed well can be collected and sold to other farmers outside Githunguri thus a source of income.

seasonal feed variation

Farmers are aware of climate change as there are unpredictable weather patterns, prolonged droughts which lasts for more than three months which was not the case there before, variations in the rainfall patterns, extremely strong winds, high temperatures, the emergence of pests and diseases. Climate change is real as there are feed shortages after every three years and that a period of drought could be experienced after every 7 years but now it's after 3 years. Farmers who had enough feed reserves did not have fluctuations in the milk production during the dry months instead their milk production increased. For those who did not have feeds, the feed costs went high increasing their cost of production and also the feeds were of poor quality. However, a focus group discussion in Olenguruone revealed that, during the dry periods, the cooperative offered poor milk prices prompting them to farm gate sales as it offered better prices, reducing the supply of the milk to the cooperative. Farmers conserved feeds inform of hay, silage and prepared homemade rations. Those that fed their dairy cows on Pineapple and brewers waste ensured they preserved a lot of it especially when the factories are closing for maintenance for a period of two weeks.

A focus group discussion in Githunguri established that, during the dry seasons, the quality of hay in the market was of poor quality and the prices were high increasing the production costs. In addition, farmers were not capable of distinguishing hay and wheat straw and that they used to smell and colour as techniques of distinguishing the two. A key informant SCLPO Githunguri encouraged them that knowing how the flowers of the two looks like would be a good method of being able to distinguish them.

Figure 14:pineapple waste preserved for dairy cows

Figure 15:Hay bales stored in a farm

Cost and revenue stream within the dairy farming systems.

The cost and revenue streams within the dairy farming systems varied from one farmer to another depending on the level of management and investments of the farm. Cost in relation to feed and A.I services were common in all farms as they all used A.I for insemination and purchased feeds. Milk production also varied as they all had different herd sizes as well as the milk prices. There were also cost saved depending on the climate-smart practice that the farmers' understudy had adopted. Table 6. Shows the different costs and revenues that the farmers incurred in their dairy enterprise.

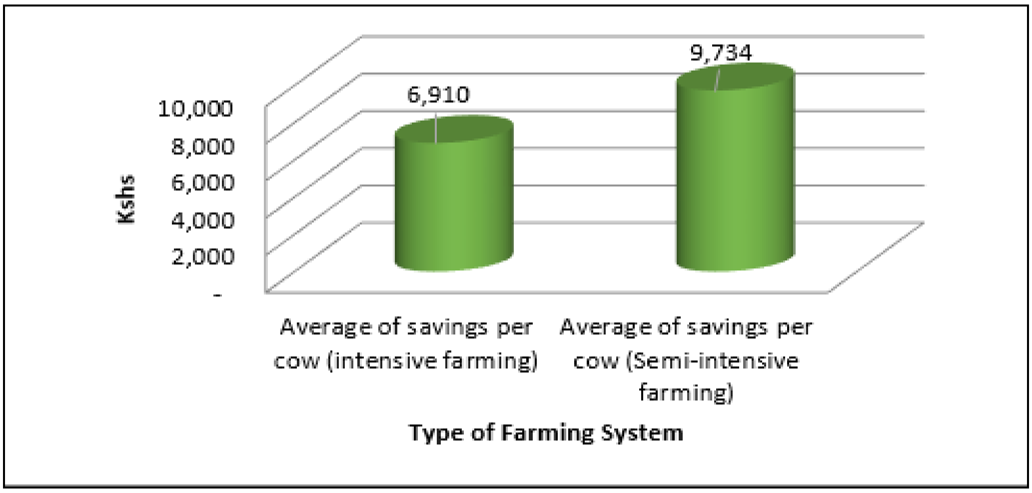
Table 6:Cost and Revenue Streams within the dairy farming systems.

Farmer	1	2	3	4	5	6
Cooperative	**Githunguri**	**Githunguri**	**Githunguri**	**Githunguri**	**Olenguruone**	**Olenguruone**
Farming system	**Intensive**	**Intensive**	**Intensive**	**Semi Intensive**	**Intensive**	**Semi Intensive**
Milk production per year (Litres)	204,316	2,240	9,553	187,610	43,800	16,425
Price per litre (Kshs)	38	38	38	40	30	30
Milk revenue (Kshs)	7,764,008	85,112	363,022	7,504,400	1,314,000	492,750
Revenue from other sources	797,050	62,730	444,740	2,036,800	1,055,250	215,550
Total revenue(TR)	8,561,058	147,842	807,762	9,541,200	2,369,250	708,300
Fixed costs(FC)	210,559	7,305	13,077	662,675	400,267	12,319
Total costs(TC)	3,462,199	184,905	310,477	6,907,475	2,153,629	216,319
Total variable costs(TVC)	3,251,640	177,600	297,400	6,244,800	1,753,363	204,000
Gross margin (TR- TVC)	5,309,418	(29,758)	510,362	3,296,400	615,888	504,300
Net profit (GM-FC)	5,098,859	(37,063)	497,284	2,633,725	215,621	491,981
Profit- cost ratio(Net profit/TC	1.47	-0.20	1.60	0.38	0.10	2.27
Total cost per cow per year (TC/Herd Size)	52,457.6	46,226.2	62,095.5	87,436.4	119,646.1	36,053.1
Net Result per cow per year (TR/Herd Size)	77,255.4	(9,265.6)	99,456.9	33,338.3	11,978.9	81,996.9
Saved costs on climate smart	288,000	12,000	-	138000	365,000	12,000
Net Profit without CSA	4,810,859	(49,063)	497,284	1,253,725	(149,379)	479,981
Net result per year without CSA(TR/Herd size)	72,891.80	(12,265.63)	99,456.87	15,869.93	(8,298.86)	79,996.91
Savings per cow with CSA	4,363.64	3,000.00	-	17,468.35	20,277.78	2,000.00

The results show the relationship between milk production costs and the returns in order to depict whether the farms were making a profit or not. The gross margin involved the examination of variable costs and the revenue of milk and sales from other farm products. Farmer 2 did not make profit as the total variable costs exceeded the total revenue.The costs included animal feed costs, veterinary, labour, milk transports and electricity bills. The results also show the cost saved by having climate-smart practices.

N:B The cost savings per year on climate-smart are estimates from the farmers based on how they spent before the adoption of the Practice.

Figure 16:Comparison of Average savings for intensive system and intensive systems of farming



Semi-intensive has more savings than intensive probably because the intensive system, dairy cows are left to graze and supplemented with feeds in the evening unlike for intensive system where animals are confined for the whole day

4.2 Climate-smart practices within the dairy farming systems.

Climate-smart practices are crucial as a mitigation strategy for the reduction of GHG emissions within the dairy farming systems. Farmers understudy had adopted and were practising several climate-smart practices in their farms despite the fact that they did not know that they were climate-smart.

Biogas production/ biodigesters.

Farmers understudy had biodigesters and the main purpose was for cooking. They used electricity to light the homestead, zero-grazing units and to operate the chaff cutters. However, one of the farmers who had recently installed the biodigesters had modified it such that it was going to be used not only for cooking but for lighting the zero-grazing unit, operating chaff cutters and also heating the rooms especially during the cold months of June – August.

water harvesting technology

Clean water is essential not only for human consumption but also for dairy animals. Without clean water, the hygiene of the zero-grazing unit is compromised as well as the milking thus contaminating the milk leading to wastages. Farmers had water tanks for storing water that they pumped from the wells as well as for harvesting rainwater which they used for home consumption and for livestock purposes. Water was pumped during the dry months but not during the rainy season as they used the rainwater.

Fodder production and conservation

Dairy production as an enterprise requires proper planning of the feed for the animals throughout the year to avoid fluctuations in milk production and increased the cost of production. Majority of the farmers in the farmers in Githunguri had Napier grass in their farms while those of Limuru and Olenguruone had Napier grass and other grasses like oats, Nandi Setaria, Brachiaria. They also had fodder storage structures where they conserved fodder in the form of hay and others had embraced silage making both trench silos and plastic /tube silage.

Figure 17:silage stored in plastic bags

Manure management

Climate-smart entails the use of manure in the crop fields and discourages the use of inorganic fertilizers. Farmer's understudy and also those in the focus group discussion alluded that they used manure from their zero-grazing units in their fodder production. They applied manure directly, solid wasted it or used the slurry from the biodigesters as well as compost. Manure reduced the cost of production as they did not purchase fertilizers, improved their soils and also increased fodder production. Farmer 2 understudy preferred to use slurry from the biodigesters than applying manure (solid dried manure) as he believed it reduces the acidity of the soil apart from adding soil fertility.

Figure 18:Manure applied in Napier grass field

Milking machines

Dairy farming, intensive and semi-intensive is labour intensive and especially for those with large herds of cattle. This implies that a lot of labour is required during cleaning, feeding and milking thus increased labour costs leading to the increased cost of production. To be climate-smart dairy farmers must be able to reduce the cost of production, increase production while reducing GHG emissions.

Technologies like milking machines are essential for clean milk production, saving time as they are efficient and reducing labour costs. There were milking machines in two farms understudy in Limuru and one in Olenguruone. In Limuru they had 4 people milking 37 dairy cows and in Olenguruone only one person for 8 dairy cows.

Figure 19:Portable milking machine

Solar panels and water baths

Electricity bills are a cost in dairy production, if well managed can be reduced. Farmers in Limuru and Olenguruone used solar panels during the dry seasons for lighting farmhouses and heating water used for milking which led to a reduction of electricity bills.They also used water baths for cooling milk overnight especially in Olenguruone as the evening milk was delivered to the cooperative the following day in the morning. Water baths prevented the milk from going bad and reduced electricity bills as they only required to dip the container containing milk in a large pool of water or a bigger container than the one with milk.

Agroforestry

Farmers in Githunguri and Olenguruone had areas set apart for agroforestry. However, Olenguruone had a large area under tree cover both indigenous and exotic and probably because they had large pieces of land. Olenguruone and Limuru practiced silvopasture where trees are planted with pasture underneath and animals can graze directly or the pasture is harvested and fed to the animals. Some of the agroforestry trees are, Grevillea, Casuarina, blue gum, Prunus Africana, Mexican green ash, croton megalorcarpus, croton macrostachycus while fruit trees avocado, lemon, green apple and papaws.

Gender smartness

Farmers in the focus group discussions both in Githunguri and Olenguruone acknowledged the role of women in dairy production. Women do most of the chores related to feeding the cows but, the income goes to the man of the house/ husband. This clearly came out in Olenguruone as the farmers there confirmed that women according to their culture are not allowed to own cattle or even handle the proceeds from dairy. Due to these, women have embarked on other enterprises like dairy goat production, indigenous chicken rearing to supplement their income and also table banking and merry- go rounds. A key informant of Githunguri dairy cooperative said that, the cooperative recognises women as they are allowed to supply milk to the cooperative and receive payment based on their production. Men are not the only ones to own cattle, as there are female-headed households either widows or unmarried. Women can access loans in the cooperative as long as they supply milk to the cooperative. Although women are allowed to supply milk to the cooperatives as men, they do not hold any management position in the cooperative as well as the youth. The youths in the focus group discussion expressed their disappointment as to why they did not fully participate in dairy production. They alluded that, their parents did not allow them to own land or share the income from dairy when they gave a helping hand in managing the cows. Many of the youths in the area of study are involved in boda boda business as it has quick money and not tedious as dairy. It was evident that, most of the youths employed in the dairy farms and other farms were not form the area of study but from other counties. This was also confirmed in the focus group discussions in Githunguri as farmers stated that, most of the workers/labourers were not from the area but from other counties. It is vital to note that most of these youths were men from 25- 50 years. Farmers said that they did not employ women as zero-grazing chores were tedious and heavy and only men could do them. Both cooperatives involved women and youths in their training farm visits a giving them equal opportunity to knowledge access as men.

Table 7:Summary of climate-smart practices

Smartness category	**Indicators**
Water smartness	Water harvesting tanks and storage tanks
Energy smartness	Use of biogas/ biodigesters, solar panels, water baths
Carbon smartness	Agroforestry, crop rotation
Nitrogen Smartness	Use of manure, bio-slurry, compost, mulching, fodder legumes and trees
Weather Smartness	Agroforestry, fodder production and conservation
Knowledge smartness	Attending farmers training, sharing dairy management knowledge with other farmers, adoption of knowledge in dairy production
Gender smartness	Equal opportunities in dairy production for women and youth e.g access to knowledge, loans

Source: Adopted by Kiiza (2018) from World bank and CIAT (2015).

Table 8:Implementation of climate smart practices

Climate Smart Technology	No. of farms
Biogas / biodigesters	66%
Water harvesting structures (water Tanks)	100%
Fodder Conservation structures and Technologies	100%
Application of Slurry and Manure in crop field	100%
Milking Machine	33%
Solar panels	33%
Water baths	33%
Agroforestry	83%

Source: Author.

Kiiza (2018), indicated the adoption of climate-smart practices with colours. Green > 60 % have adoption and implementation, yellow between 30-60 % adoption and red < 30% adoption. The table shows the level of adoption and implementation by each farmer.

Table 9:Adoption and Implementation of climate-smart practices

Climate smart practice	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6
Energy smartness						
Weather smartness						
Carbon smartness						
Nitrogen smartness						
Knowledge smartness						
Gender smartness						
Water smartness						

The observations in the farm indicated that farmers had adopted climate smart practices as seen in table 8. Farmers in the focus group discussions were however asked to rank the CSA practices identified based on their importance according to them in mitigating climate change

Table 10:Ranking of scalable climate smart practices by farmers

Climate Smart Practice	**Order of ranking**
fodder conservation	1
breed upgrading	2
biogas/ biodigesters	3
water harvesting technology/ tanks	4
manure application in the fields	5
mechanization(milking machines)	6
intensive dairy farming (zero grazing)	7
solar energy/ solar panels	8
agroforestry	9
water baths	10

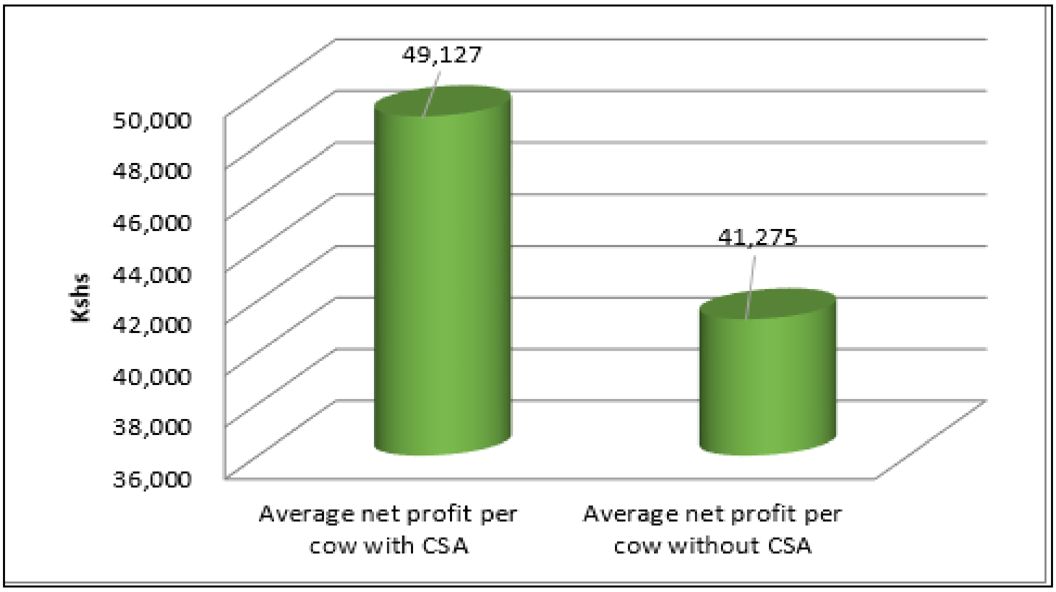
4.3 Economic impacts of climate-smart technologies.

Farmers understudy and even those that attended the focus group discussion did not know that what they were practicing was climate smart.The key informants also were also not aware of the technologies too. For the farmers practicing the technologies, the initial cost of investment was high but it cannot be compared to the benefits they are reaping from them. A cost benefit analysis was prepared based on the estimates that the farmers gave concerning the costs they were saving from climate smart. Many of the farmers acknowledged the costs saved by using biodigesters/ biogas, solar energy and water harvesting technologies per year as shown in figure 19 and figure 20. In order to arrive at an average profit per cow with CSA. Cost saved was considered as a revenue based on what the farmers had saved with the technology they were using. A net result was calculated as well as the net result per cow, all these costs were averaged (see table 6). To arrive at average cost without climate-smart, the cost saved on the CSA were considered as cost incurred in the farm and reduced from the Net result, and then averaged for all the farms (see table 6). The values were used to draw the benefit of CSA on farm.

Table 11:Net result with cost saved per year on climate smart and Net without climate smart per year

Farmer	1	2	3	4	5	6	
Cooperative	Githunguri	Githunguri	Githunguri	Githunguri	Olenguruone	Olenguruone	
Farming system	**Intensive**	**Intensive**	**Intensive**	**Semi Intensive**	**Intensive**	**Semi Intensive**	
Net profit (GM-FC)	5,098,859	(37,063)	497,284	2,633,725	215,621	491,981	
Net Result per cow per year (TR/Herd Size)	77,255.4	(9,265.6)	99,456.9	33,338.3	11,978.9	81,996.9	**49,126.8**
Saved costs on CSA per year	288,000	12,000	-	138000	365,000	12,000	
Net Profit without CSA	4,810,859	(49,063)	497,284	1,253,725	(149,379)	479,981	
Net result per year without CSA(TR/Herd size)	72,891.80	(12,265.63	99,456.87	15,869.93	(8,298.86)	79,996.91	**41,275**

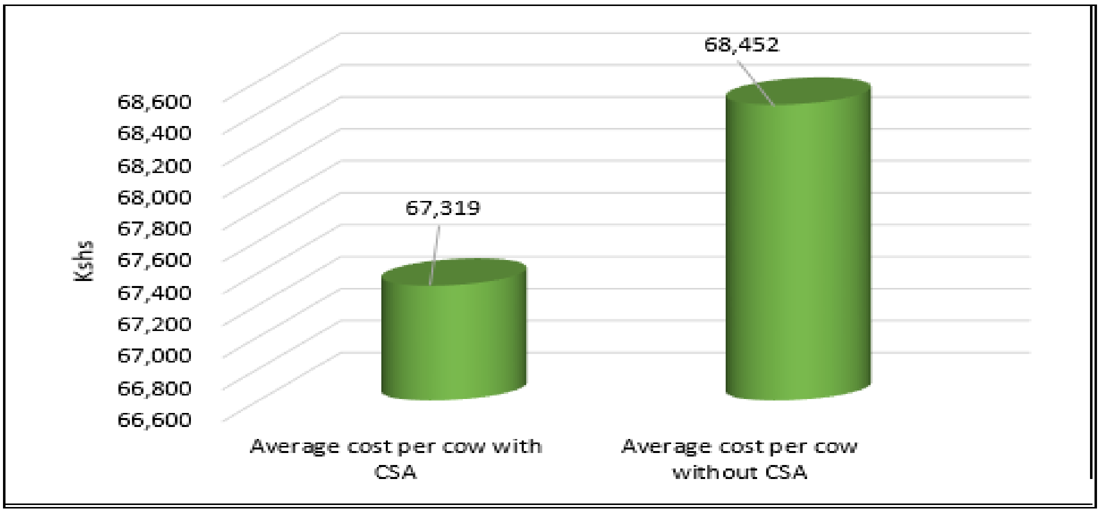
Figure 20:Average Net result per cow with CSA and without CSA practices



The average profit per cow per year in farms where CSA has been embraced was Kshs 49,127 while that of farms who did apply any CSA practices was Kshs 41,275

NB: The farms which have employed CSA practices approximately recorded per cow Kshs 7,852 higher than those which had not embraced CSA.

Figure 21:Average cost per cow climate-smart e.g solar energy, water harvesting and biogas



The results show the average cost of farming in a year for farmers who apply CSA practices per year was Kshs 67,317 while that of farms who did not apply any CSA practice was Kshs 68,452. The use of CSA reduces the cost of farming substantially by approximately Kshs 1,133. To get the average cost per cow with CSA the total cost incurred without the cost saved in the respective farms were divided by the number of animals in that farm (TC/herd size) at the same time to get the average cost per cow without CSA, the cost saved on CSA were considered as cost (TC/ herd size), they were then averaged to get the difference with and Without CSA (see table 6).

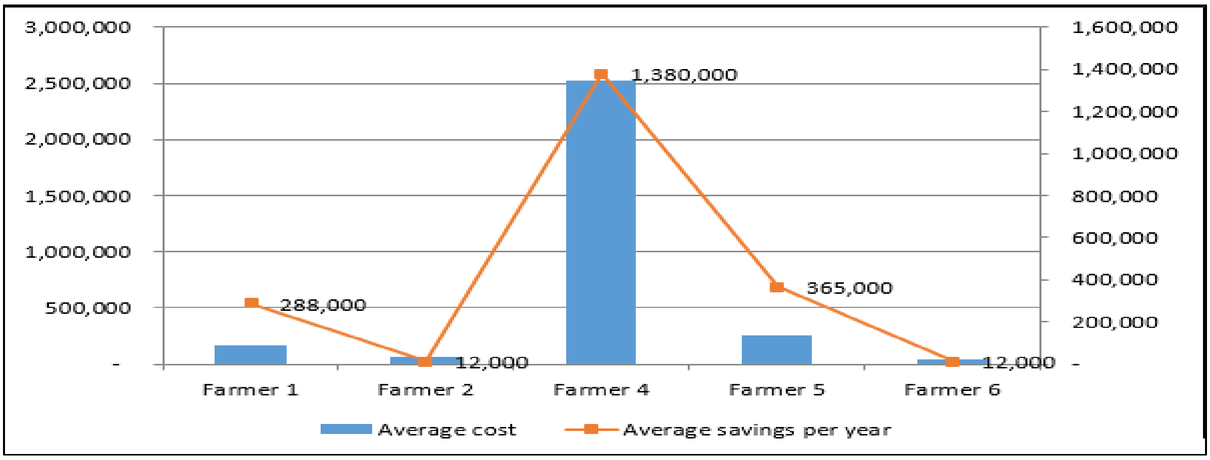
Saving per year with climate-smart practices

Farmers who had adopted and were practicing climate smart practices cited their benefits in the farm. They were able to save costs that would have been incurred without them. Therefore, it is not only about climate change mitigation but also a cost-savings strategy. The costs were estimated as given by the farmer per year.

Table 12:Costs saved per climate smart per year according to farmers estimation

Climate Smart Practice	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6
Biodigesters/ biogas	288,000	12,000				12,000
Water Harvesting					365,000	
Solar Panels				1,380,000		

Figure 22:savings per year for farmers with climate-smart practices.



From the results, it is evident that climate-smart practices are not only a mitigating approach to GHG but also a cost reduction structure as well. Of the climate-smart practices that farmers under study were practicing, biogas production, water harvesting and use of solar panels have proofed that CSA is beneficial and indeed it can help farmers to save costs.

4.4 GHG Emissions per climate smart practice

Emissions related to milk production

Fat corrected protein milk equation, (see formula A) in methodology was used for different farms depending on their production so as to be able to get the CO_2 kg equivalent as required by the IPCC (2006).

N:B 4% for butterfat and 3.3 % for Protein (IPCC 2006). To be able to account for Kenya's situation, butterfat of 4% and 3% protein for Githunguri and butterfat 3.4 % and 3.2 % protein for Olenguruone was used. The fat and protein content from GDFCS and Olenguruone Cooperatives was through correspondence from the Head of Extension GDFCS and Official from Olenguruone cooperative society and they were used to represent the fat and protein content for all the farmers understudy in the respective areas as getting individual fat and protein content was difficult.

Table 13 shows the Fat corrected and protein milk after conversion using butterfat and protein content of their respective cooperatives.

Table 13:Fat Protein and Corrected milk

	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6
Milk in litres/ year	204,316.0	2,239.8	9,553.2	187,610.0	43,800.0	16,425.0
FPCM (IPCC)	204,117	2,237.6	9,543.6	187,422.4	43,756.2	16,408.6
FPCM (GDFCS)	200,434.0	2,197.2	9,371.7	184,045.4		
FPCM(Olenguruone DFCS)					40,449	15,166.8

Butterfat and protein content in milk has an effect into the amount of Kg CO_2 emitted to the atmosphere from milk e.g Olenguruone butterfat and protein content of 3.4 and 3.2 respectively has reduced the raw milk in litres from 43,800 litres to 40,449 litres for farmer 5 and 16,425 litres to 15,168.8. This indicates that the fat and protein content of milk determines the amount of Kg CO_2eq. per litre of milk produced.

Although milk produced in the farm is a major source of income, it also contributes to GHG emissions as it produces CO_2 .To get emissions related to milk production, Tesfuhan (2018), GHG table for smallholder dairy farmers developed using the IPCC (2006) standards was used. (see table 14)

Table 14:Emission per litre (Kg CO2) of milk produced

	Milk production per year	**Emission per litre Kg CO_2**
Farmer 1	200434	1.05
Farmer 2	2197	2.49
Farmer 3	9371.7	1.40
Farmer 4	184045.4	1.12
Farmer 5	40449	1.14
Farmer 6	15166.8	0.38
Total	**451,664.1**	**7.58**

Results show that, the higher the milk production the lower the kg CO_2 per litre except for farmer six who tends to have very low emissions with low milk production. Farmer 6 does not feed the dairy cows on any commercial concentrates to supply the animals with protein but with fodder legumes produced from the farm. Farmer 1 has the highest milk production in litres and has the lowest per litre Kg CO_2 of 1.05. The total emission from milk production is 7.58 Kg CO_2.

Enteric fermentation from livestock category

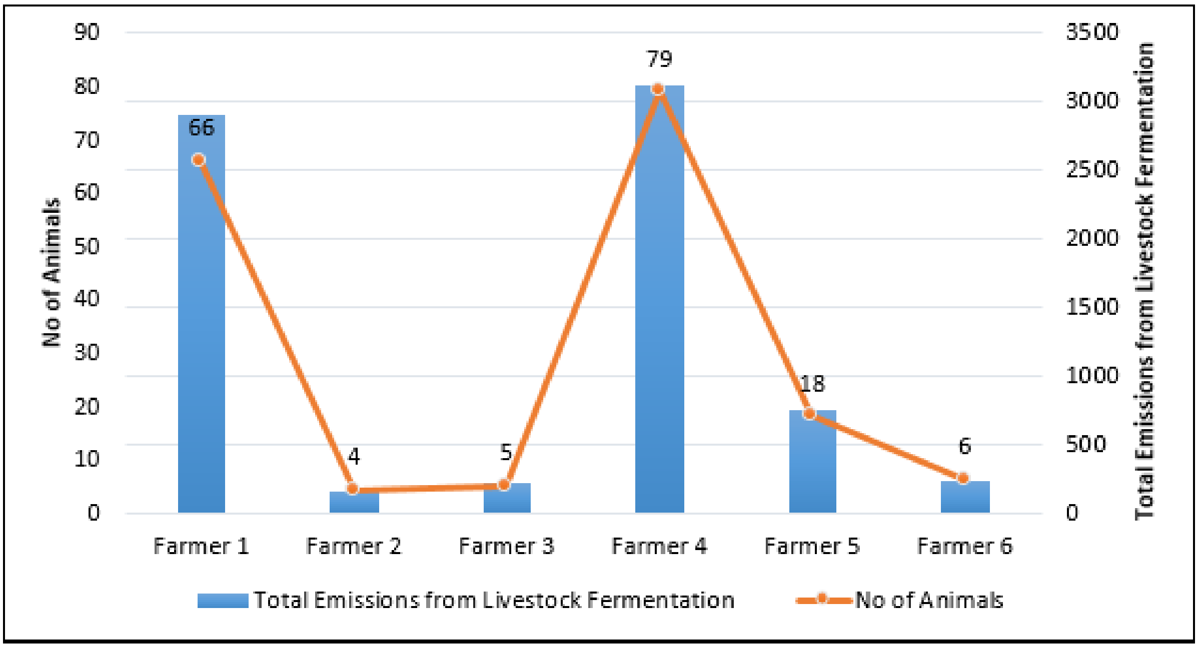
Enteric fermentation was calculated based on the category of animals in the farms under study and emissions given as Gg CH_4 yr-1. EF(T) emission factor for defined livestock population (dairy cattle 46 and young 31). Emissions were calculated for each category and then added to get the total emissions. See formula B (Enteric fermentation from a livestock category) in methodology (Tier 1)

Table 15:Total Enteric fermentation from livestock category

Category	Herd size	Emissions from Enteric Fermentation, Gg CH_4 yr-1 (dairy)	Emissions from Enteric Fermentation, Gg CH_4 yr-1 (multipurpose) e.g young	Total emissions from livestock category, Gg CH_4 yr-1	Gg CH4 yr -1 *10^6 to Kg CH_4 yr-1	Kg CO_2 eq.
Farmer 1	66	0.0026220	0.0002790	0.0029010	2901	60,921
Farmer 2	4	0.000920	0.0000620	0.000154	154	3,234
Farmer 3	5	0.0001840	0.0000310	0.0002150	215	4,515
Farmer 4	79	0.0020240	0.0010850	0.003109	3109	65,289
Farmer 5	18	0.0005520	0.0001860	0.000738	738	15,498
Farmer 6	6	0.0001380	0.0000930	0.000231	231	4,5851
TOTAL					**7348**	**195,308**

According to (UNFCC, 2017), (Rojas-Downing, et al., 2017) 1 CH_4 is equivalent to 21 CO_2 eq. Therefore, CH_4 kg per year was converted to Kg CO_2 by multiplying with 21. Results show that, livestock populations have a direct relationship with the Kg CH_4 produced. The higher the livestock population, the higher the CH_4 and in return CO_2

Figure 23:Relationship between herd size and CH4 emissions



N: B: The higher the number of animals, the higher the emissions

Emissions factors based on Gross energy intake

These are emissions are a result of the feeds that the animals are given in their respective farms. This is because enteric fermentation being a digestive process of the ruminants is dependent on feeds, forages and concentrates that the animals are fed on. See formula B. II in Methodology

Table 16:Emissions based on GE and feed intake

	Herd size	Total emission all animalsCH_4/yr	Total emission all animals Kg CO_2	Milk production	Emission per litre Kg CO_2
Farmer 1	66	9975	209475	200434	1.05
Farmer 2	4	345	7245	2197	2.49
Farmer 3	5	624	13104	9371.7	1.40
Farmer 4	79	9782	205422	184045.4	1.12
Farmer 5	18	2202	46242	40449	1.14
Farmer 6	6	275	5775	15166.8	0.38

N: B 1 CH_4 is equivalent to 21 CO_2 eq. (UNFCC, 2017), (Rojas-Downing, et al., 2017)

Results show that, the type of feed given to the animals can vary CH_4 emissions in a farm. However, milk production has a direct relationship with the Kg CO_2 produced in a farm because farms that had higher milk production had lower emissions e.g farmer 1 and 4. Results also show that, farmer 6 had the lowest Kg CO_2 per litre inspite of the milk production being low as compared to farmer 1 and 4. Dairy animals in farmer 6 farm are fed with a mixture of grass forages e.g Napier grass, Brachiaria, Nandi setaria and fodder legumes/trees e.g Caliandra, Sesbania sesban, alfalfa and with no commercial concentrate like dairy meal. The other farms animals were fed on grass forages and commercial concentrates e.g dairy meal, wheat bran and maize germ.

Emissions from Manure management

These are the emissions based on the manure management practice that each farmer carried in the farm. There are those who had biodigesters, prepared compost, directly applied manure in their farms and also solid wasted manure for a period of 3 months and over depending on when the farmer wanted to use it and also the weather conditions. Due to these management strategies, emissions on manure management differed from each farm. See formula B.III in methodology

Table 17:EF manure management

	Total manure emission Kg eq. /year	**Milk production per litre**	**CH_4 emission per litre**
Farmer 1	102	200434	0.0010
Farmer 2	14	2917.2	0.0050
Farmer 3	0	9371.7	0.0000
Farmer 4	71	184045.40	0.0000
Farmer 5	20	40449	0.0000
Farmer 6	33	15166.8	0.0002
Total	**240**		**0.0062**

Farmer 3 had the lowest emission CH_4 per litre in comparison with other farmers. Manure is managed inform of composting while the other farmers had biodigesters, solid dried manure and also direct application of the manure in the crop field. Results, show that compost manure management traps CH_4 making it unavailable to the atmosphere. Farms 1, 2 and three had biodigesters while 4 and 5 did not. For farm 5, the biodigester was installed during the research period, its emissions were not accounted for. However, it is good to mention that, storage time of the manure also determines CH_4 emissions. Farmer 2 has 0.005 CH_4 per litre as apart from using the biodigesters, the manure was solidly dried for a period of 6 months before being applied to the fields. Farmer 5 and 6 did not solid dry instead they applied the manure directly to their crop fields. From the results, it can be deduced that storage time is a factor contributing to the quantity of CH_4 per litre.

Emissions from feed production (fertilizer application)

From observations and interviews with farmers, most of them used manure from the dairy animals to fertilize their farms. Of the six Farmers, farmer four indicated that he used 100kg bag of DAP during planting in his farm while the rest used manure. (See formula II & II in Annex).

Table 18:EF Fertilizer Application

	Milk production per litre	Emission per litre Kg CO_2
Farmer 1	200434	0.000000
Farmer 2	2917.2	0.000000
Farmer 3	9371.7	0.000000
Farmer 4	184045.40	0.000053
Farmer 5	40449	0.000000
Farmer 6	15166.8	0.000000
Total		0.000053

Results indicate that application of Inorganic fertilisers contributes to GHG emissions of 0.000053 Kg CO_2 equivalent as observed in the case of farmer 4 as compared to farmers who have used manure in their farms. The use of inorganic fertilisers does not only lead to GHG emissions as seen in the results but it is also a production cost. Therefore, by farmers opting not to use fertilisers in their farms, does not only make them climate-smart but, it also saves them the cost of purchasing fertilisers thus using the money for improving dairy production instead.

Manure or fertilizer applied in the crop fields can be lost through leaching or volatilisation. farmers in the area of study applied manure directly on the surface while for those who the animals were grazing the animals deposited it directly.

Table 19:EF Volatilisation and EF Leaching

	Sum N_2O Volatilisation Kg N_2O	*Sum N_2O Volatilisation Kg CO_2 eq.*	*Sum N_2O Leaching Kg N_2O/year*	*Sum N_2O leaching Kg eq. CO_2*	*Emission direct and indirect*	*N_2O per litre*	*CH_4 + N_2O*
Farmer 1	7.38	2,287.8	6.27	1,944.2	4,266.1	0.021	0.022
Farmer 2	0.11	32.9	0.08	23.6	77.0	0.026	0.031
Farmer 3	-	-	-	-	410.7	0.044	0.044
Farmer 4	7.85	2,433.6	3.93	1,216.8	3855.8	0.021	0.021
Farmer 5	1.19	368.6	0.65	202.3	926.3	0.023	0.023
Farmer 6	0.43	134.8	0.43	134.8	269.5	0.018	0.020
Total emissions per litre	16.96	5257.7	11.36	3521.7	9765.4	0.153	0.161

N: B The GWP is 1 kg N_2O is 310 CO_2 eq.(UNFCC 2017) (Rojas-Downing, et al., 2017)

Results indicate that farmer 3 has no N_2O emissions related to volatilisation probably due to the fact that the manure is managed by compost. Farmer 1 and 4 have the largest herd size as well as the highest N_2O emissions Kg eq.

N can be lost through leaching by rainwater to the surface and end up causing pollution. Some farmers understudy had a problem of manure management as the manure would flow on the roads posing a threat to the environment through pollution. Results for direct and indirect emissions indicate that farmer 2 had the lowest emissions. The farm has few animals as compared to other farms. A direct relationship of livestock population with direct and indirect emissions in relation to leaching and volatilisation is seen.

Emission from feed transport

Farmers produced feed from their own farms but that was not sufficient to cater for their animal's nutritional needs thus, purchasing feeds and fodder from the nearby stores or far away from their areas. This contributes to emissions in the farm considering that the vehicles will deliver feed in the farm and also the management practice during fodder production. Farms understudy had different emissions based on transport depending on the distance covered and the mode of transport e.g vehicle, motorbike and also the fuel used (diesel, petrol). (See formula III in annex)

Table 20:Emissions Feed transport

	Milk production in litres	Total all feed Transport (Kg CO2)	All feed Transport Emission Kg CO_2 per litre
Farmer 1	200434	5575.91	0.03
Farmer 2	2917.2	10.0672	0.00345
Farmer 3	9371.7	50.876	0.001
Farmer 4	184045.40	402.1	0.001
Farmer 5	40449	2734.43	0.07
Farmer 6	15166.8	0	0.00
Total			0.10545

Farmer 6 produced fodder from the farm. There is no mechanisation employed on the farm as most work is done by the casual worker. A wheelbarrow is used to carry fodder from the farm to the fodder chopping area thus 0.00 CO_2 emissions. Results show that, the mode of feed transport on the farm contributes to the amount of CO_2 produced in a farm. All the other farms either used vehicles or motorcycles to bring feeds to their farms. Farmer 2,3 and 4 bought feeds in the nearby town centres to their farms. Farmer 1 bought feeds as far as Thika and Nairobi from Githunguri while farmer 5 went as far as Njoro from Olenguruone thus 0.03 and 0.07. however, in spite of the fact that farmer 1 covers less distance for feed transport, the emissions are 0.03 Kg CO_2 per litre as farmer 1. The fact is that; it has been noted that milk production in the farm influences all the other emissions on the farm. farmer 2 had the lowest milk production of 2917.2 litres per year compared to the other farmers. Fodder production and conservation as a climate-smart is evident with farmer 6 in that, although the emissions in the farm are low, it was not because of not transporting feeds in the farm, but because of producing fodder from the farm. Farmer 6 had the lowest emissions based on Gross energy and feed intake (see table 16) inspite of having less milk in litres compared to farmer 1 and 4 considering the relationship between milk production and Kg CO_2 per litre, the emissions would have been higher than the two farms (1& 4). In this case, they are low because the farmer was feeding the animals on grass forages and legumes produced in the farm not using fertilisers but manure.The animals in this farm are not fed on any commercial concentrate, thus a saved cost. Farmer 6 is a good example of how fodder production in the farm using manure and at the same time feeding quality feeds can lead not only to the reduction in GHG emissions but to saved costs.This clearly shows that climate change and productivity can be tracked together.

Since the analysis involved LCA (Life Cycle Analysis), it is prudent to account for all the emissions upstream (feed transport) and on-farm (dairy herd, feed production, manure management and on-farm feed production). Therefore, the total emissions of all the management practices are shown in Table 21.

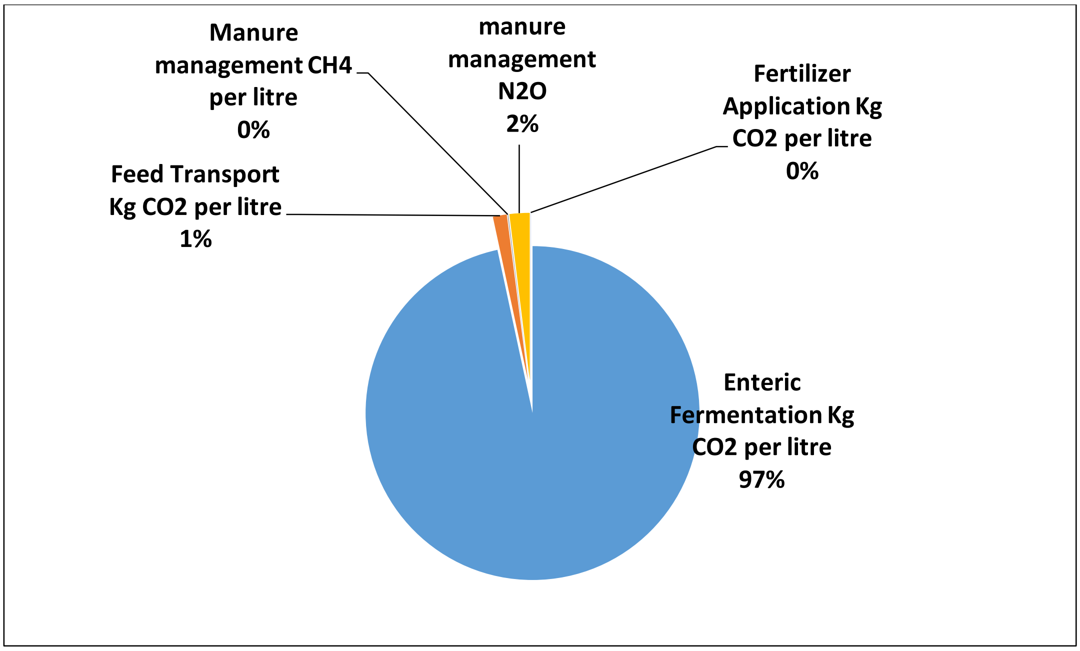
Table 21:Total Emissions Kg CO2 eq

Management Practice	Total Emission in Kg CO2 eq
Enteric production	7.58
Manure management	0.126
Feed production (Fertiliser Application)	0.00053
Feed Transport	0.010545
Manure management (CH_4 per litre)	0.062
Manure management (N_2O per litre)	0.153

NB: manure management is in CH_4 per litre and N_2O per litre

Results show that the Enteric fermentation contributes to more emissions Kg CO_2 eq. per on a farm. This is a result of the type and the quality of feed fed to the animals (see table 16)

Figure 24:Total Emissions Kg CO2 eq.



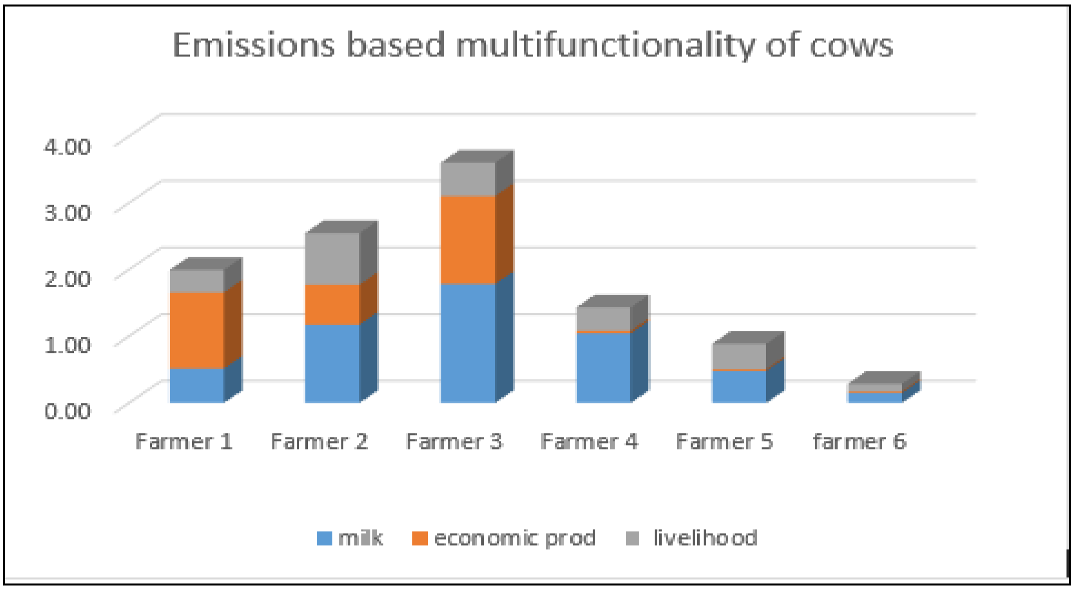
Carbon foot print Analysis

To account for the carbon foot analysis, a summary of all the emissions both allocated and un allocated was calculated. Table 22 shows both the allocated and un allocated milk and the carbon foot prints for every farm. The farms that had highest milk production showed low emissions Kg CO_2 eq / kg of milk even after allocating other functions in dairy e.g farmer 1 and 4. Farmer 6 had the lowest Kg CO_2 eq inspite of having low milk production because of the type and the quality of feed fed to the animal(see also table 16). Milk and feed type and quality are key in varying Enteric fermentation CH_4 thus Kg CO_2 per litre. Figure 24 shows the allocation of milk based on different function in a farm.

Table 22:Carbon foot prints allocation of milk

	Unallocated	**Allocated**		
	BE/ unit of milk Kg CO2 – eq / kg of milk	BE/ unit of milk food production. milk	BE/ unit of milk 2. economic prod	BE/ unit of milk 3. livelihood
Farmer 1	1.26	0.51	1.14	0.34
Farmer 2	2.87	1.17	0.60	0.77
Farmer 3	1.87	1.79	1.32	0.50
Farmer 4	1.30	1.04	0.04	0.35
Farmer 5	1.41	0.48	0.03	0.38
Farmer 6	0.42	0.15	0.02	0.11

Figure 25:Emissions based on Multifunctionality of cows



4.5 level of inclusiveness and Resilience in the dairy farming systems
Inclusiveness

Through the different key informant interviews**,** Githunguri Dairy farmer's cooperative involves farmers in decision making concerning the cooperative through annual general meetings. Research institutions e, g Egerton university carry out research and share the information to the farmers through the cooperatives. Githunguri and Olenguruone dairy farmer's cooperative societies transfer knowledge on dairy production through monthly training where different other stakeholders e.g feed and drug companies, county government (department of livestock production) are invited. Farmers in the focus group discussion acknowledged that, the cooperative through their extension officers has been key in training them once every month on Dairy production techniques and also through farm visits for increased production.The DEO Olenguruone cooperative also alluded that, cooperative membership had also increased through their extension visits and monthly training. Therefore, giving training is an important service to its members.

To allow for increased output, farmers can access foodstuffs and fodder at the cooperative stores although, they are free to purchase feeds from other stores. Farmers pay for these cost through a check-off system at the end of every month. The rural infrastructure in both sub-counties is in place as the cooperatives have made it possible by having collection Centres near the farmers and also the roads are accessible. GDFCS has collection centres in every route where farmers do not incur any transport costs for marketing their milk providing a ready market for milk. GDFCS to be able to fit the changing technology in the dairy sector arranges training for its Extension officers based on their training needs. They also have exchange visits in model farms visit exhibitions e.g breeders show organised yearly to equip and familiarise themselves with dairy production technology so as to pass the same knowledge to their farmers. GDFCS does not only invest in training it members on dairy farming but, also on the social wellbeing hence cross-cutting issues such as HIV and AIDS, home economics and food nutrition, gender issues and human rights are included during training. They are also trained on cooperative legal framework, rules and by-laws, duties, roles and regulations to ensure they are conversant with the working environment of the cooperative movement. The cooperative has a corporate social responsibility policy(CSR) which has a budget allocation and a calendar of activities that are not limited to Githunguri division but, also Nairobi and its environs where the bulk of their products are sold. The activities include educating bright and needy students, sponsoring football champions and schools prize giving day, visiting and assisting orphaned children in children homes and sponsoring the sick though sponsoring activities e.g Mater Heart run.

Women in the focus group discussion said that, although women do most of the chores in managing the dairy cows, the income from the enterprise is for the man as culture dictates that the cows belong to the men. Their source of income comes from the sale of vegetables, indigenous chicken and table banking in their women groups. The youth are not also into dairy farming as the land belongs to their parents and when they provide labour to the enterprise, the proceeds go to their parents. It emerged in the discussion that, most of the youth are involved in Boda boda businesses and other enterprises but not dairy. It was also evident that, although the cooperatives involve the dairy farmers in their decision making,women and the youths are not part of the management of the cooperatives especially the board members as it comprised of men only > 50 years of age who are retirees from previous employment. (see table 23 & 24).

Table 23:Gender participation (access and control profile

ASSET/RESOURCE	WOMEN	MEN	REMARK
Land	A	A/C	Men and women both have access to land but it is the men having control. women with control have either purchased or inherited through widowhood
Dairy animals	A	A/C	Source of prestige for men so women have no control over purchase or even Disposal
Sales	A	A/C	Women deliver the milk to the dairy but have no control over the sales. It is the prerogative of men
Labor	A	A/C	Men mostly decide the level of labor to be used
Extension /trainings	A	A/C	Men mostly attend training although it is open to registered members who are mostly men.
Coop Loans	A/C	A/C	Men control, as mostly they are the registered Coop members and have collateral. The dairy Coop gives equal opportunities to all.
Coop management	A	A/C	Men mostly in board membership although women are members of the cooperatives
Dairy Equipment	A	A/C	Men control what is to be used in the diary
Water	A/C	A/C	Both men and women have access to water both for dairy and home consumption
Zero grazing	A	A/C	Men Control the type and size of the structure to build
Income	A	A/C	Cultural Norms gives men the power to make decisions over-allocation and use finances for and enterprise.

Table 24:Daily activity profile

Activity	*MALE*	*FEMALE*
Feeding		√
milking		√
Cleaning		√
Harvesting fodder	√	√
Weeding		
Manure collection		√
Selling milk		√
Watering animals		√
Animal Health		√
Collecting payments	√	
supervising	√	√
Dairy management		√
Culling	√	
Purchase	√	
Dairy feeds	√	
Spraying	√	
Deworming	√	
AI	√	√
Cooking		√
Household chores		√

Resilience

Through observations and focus group discussions, farmers have several strategies to adapt to climate change vulnerability. To cope up with the effects of climate change changeability in dairy feeds, farmers conserve fodder as silage e.g tube silage, trench silo, haymaking, wet feeding (pineapple wastes, poultry waste (Guano), brewers waste) as well as making their own feed rations (see table 5) to reduce feed costs and feed quality feeds to their dairy cows.To increase feed availability, some of the farmers lease land where they grow Napier grass, maize fodder and Boma Rhodes harvest and conserve as silage and hay for their dairy cows.To cope up with reduced water availability, farmers have water wells, water pans, water tanks for storing pumped water from the wells and rainwater harvesting from the roof catchments. As an adaptive capacity, some farmers in the event of water shortage rationed the amount of water supplied to the dairy animals as the water is bought from the other sources affecting milk production. Others did destocking or ferried their animals to neighbours or relatives that have pasture. Women diversified their livestock by rearing dairy goats and indigenous chicken to reduce the cost of feeds and fodder and also as an alternative source of income. To reduce the cost of production due to inorganic fertilizers, farmers used manure in their crop fields. To support the farmer's resilience, the dairy cooperatives provide feeds and foodstuffs stocked at the cooperative stores .They also provide knowledge support on dairy management practices and A.I services to their farmers enhancing their resilience as dairy farmers.

Livelihood assets

These are the livelihood assets that increase the adaptive capacity of the dairy farmers. All the five livelihood assets: Natural, physical, social, natural and financial assets were considered.

Table 25:Assets in Dairy

Financial Assets	-Loan products from SACCO's -Proceeds from produce e.g Milk -Employment, pension - Cash transfers e.g. (pesa ya wazee) -table banking Loans
Physical Assets	-Cattle, goats, vehicle, Motorbike, chaff cutters, wheelbarrows, trolleys -Biogas plants -Milk collection centres -Processing plants -Farm houses -Zero Grazing units -Well, boreholes -Water tanks -Water projects -Electricity -Solar panels
Social Assets • Membership to SACCO etc • Women Groups etc	-Women groups, table banking groups -self-help groups -SACCOS -Families -Churches -Hospitals etc -Schools
Natural Assets • Land/ soil • Climate, Water	-Rivers -Climate/ Weather/ Rains -Soils/ land
Human Assets • Education • Training/ skills • Experiences	-Education -Farmer training programs -Livestock management skills -First Aid skills

Adaptation through Natural Asset

From the focus group discussions and interviews, water, soil and a good environment are the natural stock upon which farmers find the valuable resources for cost-effective dairy production. Land as a key natural asset available for farmers in Githunguri and Olenguruone,is accessed through government allocation, ancestral(Inheritance) and individual purchase.To increase the adaptive capacity to climate change of women and youth, they felt access to land required land policies to be reformed and enforced by laws to favour them.

Adaptation through Financial asset

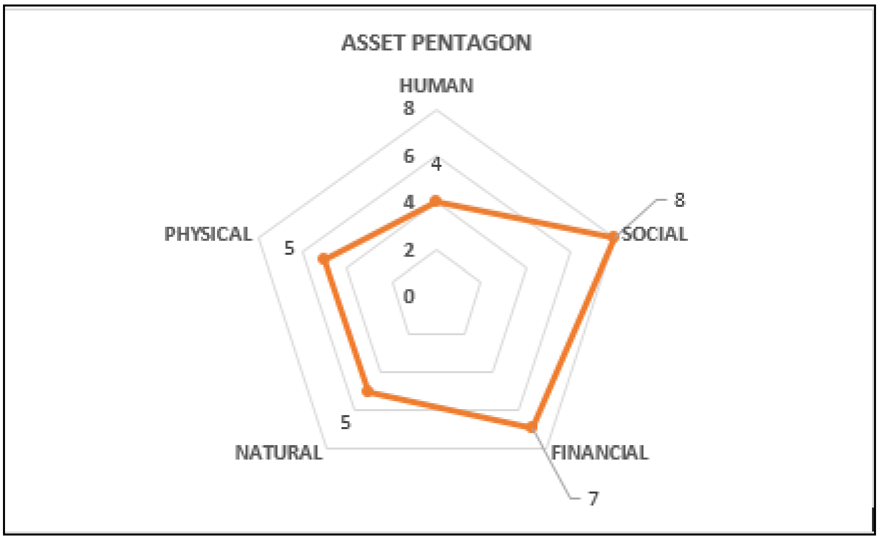
The financial asset was identified as an important asset for building the adaptive capacity during the interviews. Milk sales, income from businesses, pension, social safety nets by the government and access to credit and loans were acknowledged as sources of financial assets. Participants in the focus group discussion cited lack of finance as a hindering factor to their adaptation to climate change.18 out of 24 respondents cited lack of finance with 12 of them being women and youth.

Adaptation through physical assets

Availability of physical asset is essential for climate adaptation as revealed by focus group discussions and farm observations. Access to physical assets like chaff cutters and other dairy equipment as well as the use of cellphones for communication e.g requesting A.I services plays a vital role in enhancing adaptability. Farmers in the focus group discussion ranked the assets based on how well they were available to them.

Figure 26:Farmers in a focus group discussion ranking Assets.

Figure 27:Asset pentagon



Social capital is the membership to the cooperative society and the social groups they belong They scored high because the majority of the dairy farmers are members of GDFCS and Olenguruone cooperative. It was noted that, apart from them being members of the cooperative society, they were members of other social groups e.g women groups, church groups etc. Financial scored 7 because farmers have access to loans from their cooperatives (Mavuno Sacco and GDFCS Sacco) and have a ready market for their milk which is their respective cooperatives. They also said that they could also access loans from their various social groups. Women had table banking and merry go round where they could get loans and repay back. Human capital, scored 4 because they felt that the training they had were inadequate. They said their cooperatives arranged for them trainings once a month which they felt was not sufficient for them. They also alluded that, the farm visits were on-demand in that they had to call the extension officers if they required their services. It was noted that Olenguruone dairy cooperative had one extension officer and it was difficult for her to offer extension services to the farmers who are members of the cooperative a fact she confirmed during the interviews. The sub-county livestock production officer also commented on the same and said that as a department they were understaffed and it was difficult to offer extension services to all the farmers. He said that to meet the farmer's demand, they are working with farmer's groups and encouraged them to be in groups. Physical assets scored 5 because they felt that not all farms had assets (see figure 26). Finally, the natural asset was low because farmers in Githunguri had small land sizes due to increased population and this limited them from expansion and also proximity to the urban areas as a result of farming land being converted to settlements.

4.6 business canvass model

Since the objective of the study / project was to develop inclusive and resilient business models with the social and environmental costs and benefits, a business canvass model was developed and presented to farmers during the focus group discussion who gave their input as to how it was crucial to them. It was important to present it to them as their input is pertinent in the development of the business model and to let them know what it was. The model showed that milk production is the main income-generating enterprise with Githunguri and Olenguruone cooperatives and playing the role of the market for the farmer's milk. Farmers in the focus group discussion did confirm that indeed their cooperatives were their main customers as well as the farmers.

Figure 28:Canvass business model for Githunguri and Olenguruone dairy farmer's

<table>
<tr>
<td rowspan="2">8. Key Partners
• Dairy cooperatives (GDFC, Olenguruone cooperative, Happy cow Kenya limited
• Financial institutions e.g Family bank, Transnational bank.
• Saccos e.g GDFCS Sacco, Mavuno Sacco
• County Government of Kiambu and Nakuru (department of livestock production).
• Feed and drug manufacturers
• Research and training institutions e.g Karlo, Egerton university, Waruhiu ATC
• Kenya Dairy board
• Milk transporters Boda Boda</td>
<td>6. Key Activities
• Management and husbandry practices of the dairy cows
• Fodder production e.g Napier grass, Brachiaria,
• Fodder conservation e.g Hay, silage
• Milk delivery to the cooperative
• Practical dairy training of other farmers
• Attending monthly training organised by the cooperatives</td>
<td rowspan="2">1. Value Proposition
• Milk production</td>
<td>4. Customer Relationships
• Communication/feedback
• Mutual trust/loyalty
• Timely delivery of milk to the cooperative</td>
<td rowspan="2">2. Customer Segments
• GDFCS, Olenguruone DFCS
• Farmers (household consumption1-2 litres)</td>
</tr>
<tr>
<td>7. Key Resources
• dairy cows
• labour (casual & permanent)
• farm structures (farmhouses, zero grazing, fodder stores
• farm equipment's (chaff cutters, milking machines, tractors, vehicles</td>
<td>3. Channels
• Farmgate sales
• Direct contact with customers
• Dairy cooperatives</td>
</tr>
</table>

5.Cost Structure	9. Revenue Stream
• Salaries • Feeds and fodder costs • Veterinary costs • Investment costs (biodigesters, water tanks, chaff cutters machine milking, solar panels • Transport costs • Maintenance and repairs • Service costs (electricity bills)	• Sale of milk • Sale of heifers/ bulls • Sale of fodder (Napier grass) • Sale of vegetables, indigenous chicken • Income from cash crops(Tea) • Sale of manure • Income from farmers training
11. Social and Environment Costs • Time wasted in search of firewood, charcoal and cooking • Deforestation • Health costs associated with smoke • Erratic rainfall, high temperatures, the emergence of diseases and pests • Cost of investing in climate-smart technologies – biodigesters, water harvesting tanks and solar panels • Low quality feeds, high CH_4 emissions • Cost of rehabilitating forests • **7.58 Kg CO_2 per litre of milk produced**	**10. Social and Environment Benefits** • Increased milk production, increased sales/income, profit • A clean source of energy with no smell and not flammable compared to gas bought in the market. • Access to markets, credit and increased business opportunities • Access to health services (NHIF) through milk proceeds • Inclusion of women and youth in dairy production • Reduction in GHG emissions intensities • Dairy Knowledge dissemination to other farmers • **Cost saved by adoption of CSA technologies e.g biogas/biodigesters, water harvesting tanks, solar energy/panel**

7.58 Kg CO_2 per litre is the emission as a result of milk production as the main source of income for the dairy farmers in the area of study is milk while the benefits can be tracked based on three CSA technologies biodigesters, water harvesting tanks and solar panels. This does not mean that the other identified technologies were not beneficial but the three gave a very clear picture as expressed by the farmers themselves.

CHAPTER FIVE: DISCUSSIONS

The chapter forms on the preceding chapters presenting discussions of findings, likening results of the research with the literature done by others on the similar areas of focus.

5.1 Dairy farming systems

Intensive systems involve the confinement of dairy animals where basic housing or simple structures are provided with management level being high and optimal feed (FAO, 2018).This holds true for farmers in Githunguri and Olenguruone as they kept their dairy animals in the zero gazing units where they confined them fully.The main breeds in the system were pure Holstein Friesians, as well as their crosses. Githunguri and Olenguruone farmers produced milk which they supplied to their cooperatives and a small portion was kept for home consumption. FAO (2018), small scale farmers in the intensive system produce milk for the market selling it to cooperatives, middlemen while keeping 1- 2 litres for home consumption which is limited by the high cost of feeds. The research confirmed that, farmers under study produced and supplied milk to the cooperative which was their main market and they kept a 1-5 litres for home consumption depending on the members of household Supplying milk to the cooperatives through collection centres provided a ready market for the farmers and saved them from the exploitation from middlemen and also losses associated with looking for market thus being climate-smart.

FAO(2018), defines semi- intensive system as partly confining the animals, allowing them to graze or under paddocks and enclosing them in the evening when feed supplementation is provided.The breeds under the system being Friesian, zebu, Ayrshires, Guernsey and feed practices varying across regions which includes natural grass, improved pastures and post-harvest grazing. This aligns with farmers in Githunguri as well as Olenguruone who practiced semi intensive system of production as they confined their animals partly leaving them to graze in the field and bringing them back one hour prior to milking for them to rest and at night they were confined and feed provided for them. Farmers also kept exotic Pure Holstein Friesians breeds in Githunguri and Crosses in Olenguruone with high levels of management interms of feeding and housing. According to Thorpe et al., (2000) declining land sizes, upgrading into dairy breeds, increased dependence on purchased feeds, concentrates and forages leading to increased milk per lactation is a characteristic of small scale farmers with manure becoming a significant product in intensive crop production. Githunguri and Olenguruone land sizes are declining with many farmers opting for the intensive system of production and upgrading their breeds for increased milk production as well as using manure from their units to fertilize their fodder fields. Lardy, et al, (2008), also states that improved high productive breeds are appropriate for intensive production systems where land is limited providing better returns being efficient converters of feed. Kashangaki & Ericksen (2018), notes that feeds in intensive and semi- intensive systems range from green forages, commercial concentrates and local brewery wastes and also as a result of limited land for expansion leading to households purchasing to supplement concentrates dairy meal and maize germ. This aligns with the results in table 4 showing the type of fodder and feeds found in Githunguri and Olenguruone. Farmers in Olenguruone planted oats in their farms as a source of fodder for dairy cows which they fed it directly and conserved the excess inform of hay or silage. According to MOALF (2016), oats are becoming dominant among the small scale dairy farmers for its fast growth, palatability, high yielding being fed directly ensiled or made into hay. This is in line with the findings as oats was a source of fodder in the area of study as shown in table 4. However, this is not the case in Githunguri probably because of the diminishing land sizes and considering the fact that, it is a tea growing region as opposed to Olenguruone which is a wheat and barley zone.

Rojas-Downing,et al.,(2017), (Thornton , et al., 2009), MoALF& MoENR(2017), highlights that, potential impacts of climate change on livestock include changes in production and quality of feed and forage. This affects climate through competition for natural resources, quality and quantity of feeds, livestock diseases, heat stress and biodiversity loss. This confirms the results of the study as farmers alluded that, climate change is real and were aware of it and already experiencing its effects on their livestock and feeds. Climate change has led to unpredictable weather patterns, prolonged droughts which lasts for more than three months which was not the case there before, variations in the rainfall patterns, extremely strong winds, high temperatures, emergence of pests and diseases. As a result, feeds are of poor quality and the prices go up increasing the cost of production as well as low milk production. A key informant from the cooperative cited that, during the dry period, the cooperative almost closed down as it was not able to meet its running cost as few farmers supplied milk to the cooperative.To be able to fight back climate change, farmers have resulted in fodder conservation inform of hay, silage and some use of crop wastes e.g pineapple in order to produce in the event of seasonal variations .

5.2 Cost and revenue streams within the dairy farming systems

Muthui, et, al. (2014), states that, besides dairying contributing to the sustainability of small holder crop dairy systems through nutrient cycling to fertilise the soil, employment creation as well as providing household sustenance, it is an attractive enterprise for income generation and food security supporting an estimated 625,000 small holders' producer's households.The results of the study confirm this as seen in table 6 which clearly shows milk production is the main source of revenue for farmers in Githunguri and Olenguruone.Through the revenue generated from dairying, they have created employment for themselves and for the youths in their neighbourhood as well as from other counties in Kenya. According to FAO (2018), dairy production is a major source of employment in rural areas. It shows the importance of dairy production as a source of household income and employment creation. Manure that comes from the dairy animals is used to fertilise the fodder fields and also as a source of energy through biodigesters reducing the cost of inorganic fertilizers and fuel e.g charcoal and firewood. The high cost of feeds is the main challenge of the intensive system of production (FAO, 2018). This confirms the findings in figure 15 where the average cost savings for intensive is Kshs. 6,910 and Kshs. 9734 for semi intensive.This could be attributed to the fact the intensive have to feed their animals all the time while the semi intensive will supplement small amount only during milking as the larger share is through grazing.

5.3 climate smart practices within the dairy farming systems.

water smartness

Although farmers in the area of study were not familiar with what is being climate smart, results from farmer's interviews and focus group discussions revealed that, indeed they had adopted and were practicing climate smart practices in their farms. CSA practices were identified and summarised based on the World Bank CIAT (2015) which Kiiza (2018), adopted. According to MOALF & MONER (2017), CSA sustainably upturns agricultural production and builds the resilience of agricultural systems to climate change minimizing GHG. This holds true for farmers understudy who had adopted and were practising CSA. For instance, those who had conserved feeds/ fodder (hay, silage) and water for their livestock continued producing milk and generating income in spite of the dry season in their midst. According to (Wakhaure, et al., 2015),water availability and quality are essential to animal health and productivity and that poor quality water may lead to poor growth, reproduction and production. it is, therefore, central to consider the quality of water given to animals during the dry seasons as this is when the quality is compromised disturbing animal performance. According to (Schaller, et al., 2017), Water harvesting practices contribute to the three pillars of climate-smart by amassing productivity and income, enhancing resilience/ adaptation of livelihoods to ecosystems towards climate extremes supporting crops growth despite insufficient rains and outside growing seasons strengthening resilience and sinking and eliminating GHG emissions from the atmosphere

Energy smartness

Biogas production/ biodigesters, solar panels and use of water baths were identified as CSA practices in the area of study. Using manure for biogas production through anaerobic digestion decreases CH_4 emission from manure management and storage as the emissions are netted in the digestion process to produce biogas replacing fossil energy sources thus sinking net CO_2 emissions. The digestate having higher inorganic Nitrogen than raw manure thus less N fertiliser is required reducing NO_2 emissions (Flysjo, 2012). According to (Mooman , et al., 2011), renewable energy has a low carbon intensity with emissions per unit 1-10 % that of fossils fuels therefore effective in reducing CO_2 emission. The solar panel was also identified as a climate-smart practice and this confirms that using it leads to sinking CO_2 emissions. (Nelson, et al., 2014),solar energy trades more carbon-intensive sources of heat and power aiding to mitigate CO_2.

carbon smartness

Kiiza (2018), alluded that agroforestry, mulching, and planting of cover crops add to amassing above and below-ground biomass enhancing the build-up of organic matter thereby reducing soil disturbance. Farmers in the area of study had land set aside for agroforestry especially those in Olenguruone as they had larger portions of land than Githunguri. However, in Githunguri they intercropped the trees with crops or planted them along the boundaries. Agroforestry is vital for climate change mitigation through carbon sequestration, enriched feed thereby, reducing enteric CH_4 and for adaptation as it develops bounciness of agricultural production to climate changeability as trees strengthen, diversify production and cushion systems against risks. Trees increase the supply of quality forage, reduce overgrazing restricting land dilapidation (FAO, 2013), (Toppo & Raj, 2018). This is in line with the results as farmers under study used trees as source of fodder for their livestock e.g Grevillea, Calliandra, Sesbania sesban.

Nitrogen Smartness

Farmer's understudy applied manure that was solid dried, slurry from the biodigesters and used compost in their crop fields. This not only improved the fertility of the soils by increasing their production but also reduced the cost of purchasing fertilizers. According to (Rojas-Downing, et al., 2017), fertiliser application on animal feed crops upsurges N_2O emissions, therefore using scientifically innovative fertilisers coalescing legumes with grasses in pasture areas may lower GHG emissions in feed production. However, applying fertilisers in required quantity that the crop will absorb when it needs the nutrients by placing it where the plants can certainly reach it mends nitrogen efficiency. According to (Biala , 2011), composting of animal manure decreases bulk limiting smell, steadies nutrients destroys weed seeds and pathogens leading to the reduction of volatile organic compounds. Composting aids in the loss of carbon in manure transmuting it into more steady forms rendering the enduring carbon less decomposable when applied to land.

weather Smartness

Fodder production and conservation inform of silage and hay were considered as climate-smart as it was a strategy that prepared farmers well during the dry seasons. Those who had produced and conserved their own feeds did not experience fluctuations in milk production as well as their income during the dry seasons. Enhanced feed management by storing feeds, making better use of feeds by merging diverse types of feeds, growing grass varieties suitable to the agro-ecological zones and fodder conservation are climate-smart practices (FAO, 2015).

Knowledge Smartness

Farmer's understudy attended monthly training organised by their respective cooperatives in order to get knowledge on dairy managements practices for increased milk production. Some also used their farms for practical dairy training where other farmers came to learn practical skills in dairy management. According to a key informant from both the cooperative 70% of the participant were women. It was also noted that their workers do not attend the trainings together with their employers, but they do share the knowledge with them. This is because of the societal status that does not allow workers to interact with their employers in social places. The sharing of knowledge to other farmers is in itself a climate-smart strategy as more farmers acquire knowledge for increased dairy production and income.

Gender smartness

According to (Katothya , 2017), (Kiiza , 2018), activities that are done on daily basis such feeding, watering are performed by women and that women happen to be more responsible for livestock activities carried out around the homestead. This holds true for the farmers in Githunguri and Olenguruone as they acknowledged that women played most of the roles related to dairy management and other daily household chores while men carried seasonal tasks. Although women are known to carry out daily activities, men especially the youths are also performing out the same tasks and this is as a result of labour employed in the farms. Cleaning of the zero-grazing unit is viewed to be a difficult task for men and that is why the labourers in the farms were mostly men but in the absence of the worker's women are left to carry the same task. Although women were members of the cooperative, it was evident that they did not hold any position in the management of the cooperatives. Katothya (2017), states that, the participation of women at the management and leadership levels at the cooperatives is limited, aligning with the findings. Cooperatives should consider including women in the leadership positions considering the fact that they carry most of the activities relating to dairy management and therefore with this experience they are also well able to provide valuable information for increased dairy production. According to FAO (2017), women hold a vast of important knowledge that can advise the re-evaluation of agricultural practices that are called for under the CSA. it is, therefore, crucial to consider them in management practices as well the youths.

5.4 Economic impacts of climate-smart

Climate-smart agriculture assimilates three extents of sustainable development, economic, social and environmental by together addressing food security and climate challenges. Sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change and sinking/ removing GHG emissions where possible are its main pillars (FAO, 2013).This definition clearly depicts the benefits that farmers who practicing CSA in their farm achieved. They revolve around these three pillars in that, farmers saved costs, were able to withstand drought and continue producing milk and earning income by being climate-smart. By using biogas , saved fuel cost, rainwater harvesting, the cost of pumping water and buying water and electricity costs for using solar panels/energy. This addresses the reduction in emission intensity while maintaining milk production thereby tracking climate change and productivity together.

5.5 Emission related to milk production

Correcting milk yields for fat and protein content standardizes estimates of the amount of milk to a common energy basis (FAO & ILRI, 2016). Results show that the amount of milk production was normalized based on the fat and protein content of their respective areas which was helpful in accounting for emissions related to milk production in these areas. The emission intensity of milk production is lowest in developed areas of the world below 1.7 kg CO_2-eq/kg milk compared with regional averages reaching as 9kg CO_2-eq/kg milk. Higher milk production infers a shift in the cow's metabolism in favour of milk and reproduction as opposed to body maintenance thus lower emissions (Gerber, et al., 2013), (FAO, 2013). Kenya is a developing nation, the results confirm the highest emission as a result of milk production were 2.49 kg CO_2 with total emissions being 7.58 kg CO_2 eq/kg (see table 14). Milk production is seen to have a relationship with CO_2 emissions as farms with higher milk production per litre had lower emissions in terms of kg CO_2 eq compared to those with lower milk production as seen in Table 14. Farmer 1 had the highest milk production of 200434.0 litres with 1.05 Kg CO_2. farmer 6 in spite of low milk production, the emission intensity was low. This is as a result of the farmer not feeding the dairy cows with any concentrates but fodder legumes.

5.6 Enteric fermentation related to livestock category

According to (Rojas- Downing, et al., 2017), CH_4 emissions in Africa are anticipated to heighten due to the livestock population.This implies that there is a need to check on the livestock populations to reduce emissions (see table 15). However, it should be noted that the above results were based on Tier 1 where the EF (Emission factor) for animal categories are given (dairy 46, young stock 31). Therefore, the method that does not account for differences in Physiological state, diet characteristics, management in the given population.

5.7 Feed and Enteric Fermentation

Enteric fermentation is reliant on feed composition and feed intake hence CH_4 emissions. increasing forage digestibility and digestible forage intake eases GHG emissions from rumen fermentation and stored manure, therefore, suggested as a mitigation strategy (Gerber, et al., 2013). Table 16, show the relationship between the type and quality of feeds with enteric fermentation. It also shows that, milk has a direct relationship with emission Kg CO_2 per litre. Farmer 1 and 4 had higher milk production therefore 1.05 kg CO_2 per litre and 1.12 KgCO_2 per litre. However, farmer 6 had the lowest emission Kg CO_2 per litre inspite of having less milk in litres in comparison to Farmer 1 and 4. Dairy animals in farmer 6 farm are not fed on any commercial concentrate but on grass forages and fooder legumes. All the other farms under study fed their dairy cows on grass forages and commercial concentrates e.g dairy meal, wheat bran and maize germ. Legume silages have benefits over grass silage due to their lower fibre content also substituting inorganic nitrogen fertilizer which is an additional benefit (Gerber, et al., 2013). Although the farmer did not have legume silages, the animals were fed on fodder legumes. According to (Thornton & Herrero, 2010), CH_4 per unit of output can be reduced by better quality diets reaching a target quantity of animal product at lower CH_4 emissions with fewer animals usualy. There is need to check on the diet composition of the animals to reduce CH_4 as the loss implies loss of energy that could be used for milk production and maintenance. Use of concentrates in the farm can therefore vary enteric emiisions hence CH_4

5.8 Emissions from Manure Management.

According to (Rojas-Downing, et al., 2017), storage time and anaerobic treatment have a direct relationship with methane emissions. Mitigation measures are a task to apply because of spreading of manure on pasture even though manure placed on pasture produces N_20 emissions. Therefore, limiting storage period, improving timing and manure application, use of anaerobic digesters, covering the storage, using solid separators and changing the animal diets are some of the modification measures employed. Anaerobic digesters condense CH_4 emissions while generating biogas. They retain manure under anaerobic environments arresting CH_4 while combusting thus generating energy. Results show that, the anaerobic digesters did not only play the role of GHG mitigation, they also generated energy in the form of biogas that the farmers used for cooking. This did not make them climate-smart in reducing CH_4 but in saving costs associated with fuel. Ericksen & Crane (2018), also confirms that, biodigesters do not only produce slurry for the farms but capture CH_4 used as energy for households and that by covering manure to sustain anaerobic settings reduces N_20 and CH_4 emissions. However, if manure is not spread on pastures but left in heaps on the ground, more N_2O is lost to the atmosphere through volatilisation (Gaiten, et al., 2106). Since some of the farmer's solid dried manure before applied it to the farm while others applied it directly, this had an effect on the total CH_4 emissions in their respective farms. The results, therefore, send a message that by using biodigesters in the farms is not the only remedy to the reduction of CH_4 but also improving the time that manure is stored before application and also covering manure during storage which was not the case.

5.9 Fertiliser application.

Manufacture of N fertilizer, use of manure and urine on pasture crops, manure storage, energy used for fertilisation, field operations, drying, processing of feeds crops and fodder lead to CH_4, CO_2 and N_20 emissions (FAO, 2010). In table 18, when farmer 4 applied fertiliser(DAP) in the crop fields, there were CO_2 emissions of 0.000053 kg CO_2 eq while the other farms did not account for as they did not use fertilisers. The farm also higher emission related to N_20 volatilisation and leaching. Rojas-Downing et al (2017), N_2O emissions are increased by fertilizer use, agricultural Nitrogen fixation and Nitrogen deposition. This gives a clear overview of the role played by fertiliser application during fodder production of contributing to GHG emissions.

5.10 Feed transport

Transportation of feeds from the manufacturers or retailers to the farms resulted in GHG emissions in the form of CO_2 with farms that covered long distances having minimum emissions. Transportation of livestock products to retailers and feed to livestock farms contribute to GHG emissions with higher GHG emissions resulting from long distance (Rojas-Downing, et al., 2017).

5.11 Total farm emissions LCA (Life cycle Analysis)

The major contributor to climate change that is producing substantial emissions of CO_2, CH_4 and N_2O is the livestock sector.Livestock contributes to climate change by emitting GHGs directly through enteric fermentation and manure management and indirectly from feed production activities and conversion of forests into pasture (FAO, 2013). The results of the study showed that, enteric fermentation manure management and feed production through application of fertilizers indeed contributed to GHG emissions. According to (Gaiten, et al., 2106), more CO_2 eq is emitted through enteric fermentation than CH_4 and N_2O emitted from manure together. This is confirmed by the results in figure 23 and table 18. Enteric fermentation proved to be the key emitter of GHG emission in the farm and basically, it was as a result of the livestock populations and feed given to the animals. The farm that animals were fed on grass forages and legume forages had the lowest CH_4 emission in spite of its low milk production. This indicates that if the performance of the animals in terms of milk production is improved and the diet emissions in the farm can be reduced. According to (Misselbrook, et al., 2013), manipulations of the diet can lead to reductions in CH_4 and N while having no negative result on productivity. Use of dietary additives with precise inhibitory properties in rumen CH_4, manipulation of the in-house diet composition predominantly with respect to protein content. According to (Rojas-Downing, et al., 2017), feed composition and intake can vary enteric fermentation hence CH_4 emissions. This clearly shows why emissions in the farms varied based on the composition of the feed the animals fed on.Table 4 shows homemade rations that farmers formulated for their animals not only as a climate mitigation strategy but also to supply quality feed to their animals as they stated that most of the time the feeds they bought were not quality and affected their milk production.

According to (Gerber, et al., 2013), enteric CH_4 emissions means a loss of energy in a production system as part of the energy that is consumed as feed is lost in the form of CH_4 instead of being integrated by animals and used for production. The feed is the main production cost element as producers struggle to produce feed or bring animals to pasture and therefore, wasting part of the energy in the form of CH_4 is not only a climate change concern but also reduces production. This clearly brings the realization that, the farms were not only contributing to GHG emissions but, also to production losses in terms of feed cost thereby affecting the performance of animals. It is therefore prudent to note that, reducing the level of CH_4 emissions means cutting the cost of production and therefore profits.

5.12 inclusiveness

According to (Solomon, et al., 2017), to allow for increased input and output, market access, rural infrastructure needs to be in place with farmer's organizations having a crucial contribution to make to the development of agriculture and rural communities. This is clearly seen in Githunguri and Olenguruone cooperatives as they have provided a ready market for the milk that is produced by the farmers in their areas. To allow for increased input and outputs, the cooperatives have employed extension officers who provide extension services through farm visits and farmers training on dairy management practices and on cross-cutting issues organised every month by the cooperatives. The cooperatives allow farmers to get feedstuffs as well as foodstuffs from the cooperative stores on credit and they pay through check of the system. Farmers can also access loans in the cooperative SACCOs to improve their dairy production, this way the development of agriculture and rural communities is realised. Githunguri dairy cooperative is a good example of a farmer's organization that is making contribution to the development of agriculture and rural communities. The the cooperative does not segregate small producers supplying milk as low as 5 litres with those supplying as much as 100 litres per day. They are all considered as important members of the cooperative and due to this most farmers have grown from supplying the 5 litres to 100 litres. The increase in milk supply to the cooperative implies that this farmer has not just increased his/her income but also has improved the living standards. The rural communities have also benefited in terms of employment as many youths from different counties are employed in the dairy farms and are paid from the income from milk.

Minah, et al., (2018), states that, inclusiveness as a concept can be static and expected outcome measured alongside predefined indicators by means of standardized quantitative methods assessing to what degree different groups are present in a particular program. It is also a process-oriented – approach that takes place between different actors in society explaining how informal and informal rules of inclusion operate. This holds true for the study as it was evident that although women and youths are members of the cooperative, they are not included in the board management as it is only the men >50 and who are retirees from former employment or have been members of the cooperative for long. Culture as an informal rule of inclusion is clearly defined what a woman can own and the division of roles between men and women (see table 23& 24).

5.13 Resilience

Faures, et.al (2013), states that, resilience is the ability of systems, communities, households or persons to prevent, mitigate or cope with risk and recover from the shock. Githunguri and Olenguruone dairy farmers have been able to cope up with climate change variability in different ways. To cope up with feed shortages and seasonality, they conserve fodder in the form of silage and hay and store them in their fodder structures. Some also feed their dairy animals on plant wastes e.g pineapple wastes, brewer's yeast and others made their homemade dairy ration. To cope with water shortages, they had water tanks where they harvested rainwater. These strategies helped them to cope with drought as many of them confirmed that their milk production did not decline during the dry season as it would be expected instead they had increased milk production. conservation of fodder not only saved them from the cruel hands of drought but from high costs associated with feeds during the dry seasons but also contributed to the reduction of emissions associated with transport. fodder conservation and water harvesting, in this case, are not just a resilient aspect, they also contribute to climate-smart in the reduction of gases and economically in cutting down feed costs.

Livelihood strategies of a dairy farmer are reliant on both the on the farm and off-farm activities to cope with risks associated with dairy farming (Faures, et al., 2013). This is clearly seen in (table 25) outlining the assets in dairy. According to Abera (2018), to further develop the resilience of dairy farmers and to ensure the sustainability of dairy, dairy farmers should be aware of the capacities of resilience such as absorptive, adaptive and transformative capacity in an efficient and effective manner to deal with various risks. This is clearly seen in (table 25 &Figure 26), where farmers identified the various assets and ranked them.

5.14 canvass business model

CSA is the integration of the three dimensions of sustainable development economic, social and environmental together addressing food security and climate challenges (FAO, 2013) The objective of this study was to develop inclusive and resilient business models with the economic, environmental and cost-benefit component and therefore in line with the three dimensions of CSA. However, Groot, et al., (2018), states that studies focusing on adoption of CSA technologies in a development context identify low awareness of climate change, limited understanding of what works in different agro-ecological systems and difficulties in proving the added value of CSA technologies as factors constraining adoption of CSA. Therefore, to prove the added value of CSA, a business model was developed that showed the importance of CSA technologies. It is evident that the initial costs of investments of the technologies are higher e.g biogas, but the benefits achieved in terms of reduction of GHG emissions and cost saved are not comparable. It is, therefore, possible to track together productivity and climate change by adopting CSA technologies.

5.2 Reflection as an Independent Researcher

Conducting research is not an easy task and requires a lot of different steps to execute to arrive at the final result. Starting from understanding the problem, framing the research questions in the early stage, in creating the research findings and conclusions. The iterative process is a continuous ongoing process with the ambition to gather knowledge regarding the problem identified. It is a requirement for the masters students to carry out research in their home countries and if possible with their employers as their commissioner. My commissioner was not my employer and therefore I went to a different area. This taught me the importance of planning in advance before the actual research which I would not have done if I went to my work place. I had to call and email to Githunguri while still in the Netherlands to express my interest in collecting data with their farmers. Being away from my employer meant I was independent. This helped me to focus on my research.

Since this was a follow-up and indepth study of the previous study carried out by CSDEK 2018, It required that I stay in the farms for 3 to 4 days collecting data. This helped to get I got a lot of information that I would not have got for one day and every day was a new experience since I learned new things. If it was for a day, I would have gone without a lot of information because chances are that the farmer would not have been able to answer my question in one day. Being in the farm for those days improved the reliability of my data in that after transcribing, I would identify gaps and make them a priority the following day. Farmers themselves would also open up and tell me whatever information they had forgotten to give and felt it was relevant for my study as I would brief them once in their farms. This also improved my interwieving and commuinication skills because I had to study the attitude of the farmers , the day I step in their farms and therefore know how to communicate with them.

I contacted Catherine APCM 2018 alumni who linked me to the head of Quality Assurance and Extension of Githunguri Dairy cooperative society Mr. Kariuki through a phone call while still in the Netherlands. My supervisor Mr. Marco also gave me the contacts to Mr. Kanyari who is also an APCM alumni in Nyandarua because I was to collect data too there. It is important at this point to mention that the response I got from Mr. Kariuki through correspondence was positive as he stated that CSDEK had worked well with them and even after data collection they continued working together. I learned that, as a researcher, keeping good relationship with the people at the ground will either open or close the door for others. If CSDEK 2018, had conducted themselves in an unworthy manner or did not cooperate with the cooperative staff and especially the extension staffs my entry to Githunguri would have been very difficult 'Kudos CSDEK 2018'.

I had carried with me the CSDEK 2018 practice briefs which I handed to quality assurance department and to the management of Githunguri. The practice briefs were important for this research as they gave the cooperative the results of the previous study addressing the gaps that the cooperative needed to fill for increased milk production. As a researcher, handing over CSDEK 2018 briefs communicates a very important message to me that, once you conduct research in a particular field, it is not just about analysing it, writing reports and keeping it in the archives for your references, it is pertinent to share the findings with the people concerned as they were part of the research and in fact the findings belong to them not you. The practice briefs were also important to me as they helped me to understand the kind of research I was involved in and in problem identification as i refered to them when I got challenged in the process of proposal writing.

I did a pleliminary presentation of my findings during data collection in Githunguri and Olenguruone and focus group discussions. Farmers present and the key informants acknowledged that what I had presented was indeed what was happening on the ground. This was important in triangulating and confirming that I had collected the right information for my research and also if my data was reliable. The focus group discussions also helped me to confirm whether the information I had from farmers indeed was what was happening with the others. The issues of gender came out so clearly during the focus group discussion than in farmers interviews. I learnt that it is good to collect data from different sources to increase data precision. I also attended an alumni and a dairy workshop where I interacted with them and other researchers. I learned the importance of networking as some of them I have called them for advice during process of writing my thesis .

When I travelled to Kenya, Lower Eastern ASK show was happening, at Machakos. If my commissioner was my employer, I would have participated first in the Ask show before embarking on my research. I would be allocated duties and this would have really compromised my work. At the same time, collecting data in my home area, to some extent would have created biasness. This is because, I am familiar with the area, the people and also considering the fact that before I left I used to compile sub-county and county livestock production reports maybe I would have overlooked issues and assumed them instead of getting the information from the ground. Working independently from my employer and also fellow staffs gave me all the time to concentrate on my research work and also created in me the enthusiasm to really know the situation as it is as this was a totally different area of research from what I know. It also gave me the opportunity to interact with the extension in Githunguri and Olenguruone and would consult them on issues I found difficult on the ground. I was also able to reflect on what had happened during the day by transcribing my work where I would identify the gaps and make efforts to get the information. As I reflect on this, if I had worked in my home area, chances are that I would have identified that I had missing information while back from the field which would have been difficult to get it all. By this, I don't mean that I never communicated after I came back from data collection but it was where I needed clarification but on very few occasions.

Before I left for Kenya, my sample size was n = 4 for Githunguri cooperative and n = 2 for New Ngorika cooperative. This was not case as it turned out to be n = 2 for Olenguruone dairy cooperative. I communicated to the New Ngorika cooperative before going to Kenya but they were not responding. I informed my supervisor who advised that I accompany the VHL alumni and others who had studied in various dairy training centres for a visit to Olenguruone. We visited two farms together and I requested the farmers together with the SCLPO Kuresoi south for permission to carry data in their farms. they agreed and that’s how n = 2 for Olenguruone came up. Before going to Olenguruone, the Extension officer Githunguri had accompanied me to Ruiru and we had identified a farm that I was to carry data the following week. My supervisor suggested that since CSDEK was carrying out data in Kenya and Ethiopia, there a farm with milking machine was part of the study, I look for a farm with milking machine too. This meant that I had to stop going to Ruiru too and stay in Githunguri. All these changes taught me that, as a researcher, you need to be flexible, make room for changes, absorb them bounce back and move on and be time conscious. Communication is very important in research as it is good to communicate with the people concerned about what is happening on the ground and make adjustments early enough then to wait until the last minute. All this time my supervisor was aware of the changes that were happening with my methodology. Going to Olenguruone made my data diverse as this was a completely different from Githunguri not only ecologically, but socially.

My research was not without limitations. GDFCS assigned me the dairy extension Officer for route 3C and 1 A, as every DEO has his/her area of jurisdiction. I shared with him the kind of farmers I wanted to work with and that I required to be on a farm for a maximum of 3 days. He was was very important in helping me identify the farms as they were his farmers. He introduced me to the owner of the first farm I was to start working , the reason for being there and for how long I was to be there. It did not go well with the farmer especially the wife, they thought I had other reasons for being there not for research. This is because they are used to people with questionnaires asking them questions within 45 minutes and they are gone never to go back. Mine was was a different case. It was very difficult for me the first day because I could not move in the farm alone, whenever I moved to any part of the farm away from the workers and the owner, a person would be sent to see what I was doing. I talked with the farmer, convinced him that, only I was interested in collecting data and nothing else. I had to become an extension officer and talk to him about climate-smart to make him understand the whole issue of my being there. We got along well and by the time I left the farm we could communicate well, he gave me his cell phone number, and he permitted me to call him in case I found that I had gaps in my data and he would assist. As a researcher, it is good to work with people you find on the ground (Extension officers), as they are of great assistance in linking you with the community. I owe a lot to the Extension officer because if it was not for him assisting me to reach farmers, I would not have been able to collect data.

Getting a farm with a milking machine was not easy. There were farms in Githunguri but, the owners were only available on weekends to give me the information I wanted. We spent the whole day looking for farms and ended up with no farm. I called my supervisor in the evening informed him of my struggles and advised me to continue with Limuru as it was also supplying milk to Githunguri and that is why the DEO took me there. As a researcher, my moving from one farm to another for the whole day has taught me that, there are times things work against you and this does not mean the end of research. You must learn to handle crisis, be patient and move on. At this point, it is important to acknowledge the efforts others have played in your life. I am so grateful to Githunguri dairy cooperative management especially, the extension department and the farmers. Olenguruone dairy cooperative society, farmers and the SCLPO Kuresoi south have been very instrumental in this research, helping me to reflect and sharpen my skills for further research in the future.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Scalable climate smart practices

Farmers ranked fodder conservation as a priority CSA practice that they would want upscaled among others simply because, they felt that fodder conservation was an adaptive capacity in the event of climate change. Results from the study showed that, biogas production can be climate smart by trapping CH_4 emisions per litre released by manure to the atmosphere. Apart from biogas being climate smart, farmers saved fuel costs by using it. It is therefore, not a GHG mitigation practice but a cost reduction strategy in the farm. Water harvesting tanks saved the cost of pumping water from the well and solar, reduction in electricity bills. Therefore, GHG emissions and productivity can be tracked together and that the value proposition of climate-smart practices can be proved to the farmers. Although, farmers ranked the CSA practices and the results of the study showed their importance in sinking Kg CO_2 eq.,enteric fermentation, CH_4 is the major source of emissions in the farm due to the type and the quality of feeds. Concetrates increased emissions, thus considering the quantity given to animals. Therefore, scaling feed production and the type of feed that is given to animals will be cruicial in the reduction of CH_4 emissions.The quality and the type of the feed will determine milk production hence emissions Kg CO_2 per litre

The inclusion of women and youths in dairy management is limited. Dairy production should be made attractive to the youths to ensure its sustainability. Climate change is affecting both the large ruminants(dairy cows) that men have control as well as the small stock (dairy goats, indigenous chicken) and crops that women and the youths are involved with. women and youth participation in the dairy industry should be encouraged by supporting and recognising their distinctive roles. Therefore, their inclusion in the CSA business models should be encouraged as supporting men, women and youths in overcoming climate smart associated challenges to improve their livelihoods is an significant CSA approach.

6.2 Recommendations

VHL consortium

- The impact of climate smart practices in the dairy farming systems and the cost benefit analysis can be evaluated. Enteric fermentation as a result of the type and quality of feed contributes a lot to on farm emissions. It is therefore recommended to upscale the type and quality of feeds dairy farmers are feeding their dairy animals by creating awareness of the importance of feed in GHG emissions.

To small scale farmers

- In order to reduce production costs, avoid wastages in feeds and especially concentrates by feeding the right quantities. Fodder production from own farm is important as it guarantees quality fodder because of proper management. However, those with small land sizes can form groups, where you can contract fodder producers to produce fodder for you and you, are guaranteed of quality.
- Manure management is key to GHG reduction but also as an income-generating enterprise. It is important to collect manure and store it to be sold to other farmers and avoid the running of manure along the roads from the farm.

- Adoption of climate-smart practices e.g biogas, water harvesting, fodder production and conservation as they are beneficial in saving production costs in the farm.
- Involve the youths and the women in the dairy enterprise for the sustainability of it in the event you are old or gone.

Dairy cooperatives

- Creation of awareness on the CSA practices within the farming systems through Extension.
- Assist farmers in the implementation of CSA technologies through loans with affordable interests.
- Capacity building farmers on the preparation of homemade rations for quality feed and save the cost of purchasing commercial concentrates and also the feeding management of dairy cows.
- Capacity building on hygiene and condition of the zero-grazing units for clean milk production.
- Train farmers in manure management especially covering of manure during storage to reduce GHG emissions.

Stakeholders and policymakers in the dairy industry

- Provision of an enabling environment that encourages investors to make mechanization more affordable for small scale farmers.
- Well defined information and technology on how information is transferred from professionals (custodians) to the dairy farmers especially in the advent of devolution.
- The biogas/ biodigesters companies to install biogas in such a way that they can be connected to the chaff cutters and also lighting the zero-grazing units to reduce the cost of electricity. This is because most of the biodigesters are only used for cooking and there is still potential to be tapped in them.
- There is a need to work together in sharing the Knowledge of CSA technologies to the farmers.

References

1. Abera, J. F., 2018. *Assessment Of Resilience Of Dairy Farming In Bishoftu and Asella Areas, Oromia Regional State,Ethiopia(Doctoral Dessertation).* Addis Ababa, Ethiopia: Addis Ababa University.
2. Baars, R., 2017. *Business Models Ethiopia and Kenya Dairy Chains.* Project Document: NWO-GCP-CCAFS.
3. Biala , J., 2011. *The Benefits of using Compost for Mitigating Climate change,* Sydney south: Department of Environment, Climate Change and water NSW.
4. Common wealth of Australia, 2006. *Introduction to Cost- Benefit Analysis and Altenative Evaluation Methodologies.* ISBN 1 921182 00 8 (print) ed. Australia: Department of Finance and Administration.
5. County Government of Kiambu, 2018. *County Integrated Development plan 2018-2020,* Nairobi: Government of Kenya.
6. County Government of Nakuru, 2013. *County Integrated Development Plan 2013-2017,* Nairobi: Government of Kenya.
7. De Vries, M., Yigrem, S. & Vellinga, T., 2016. *Greening Ethiopia Dairy Value chains: Evaluation of Environmental Impacts snd Identification of Interventions for sustainable Intesification of Dairy Value chains,* Wageningen: Wagenigengen Livestock Research.
8. Duveskong, D., 2003. *Soil and Water Conservation, With a Focus on Water Harvesting and Soil Moisture retention. A study Guide for FFS and Community based Study groups..* Harare, Zimbabwe: Farmesa.
9. Ericksen, P. & Crane, T., 2018. *The Feasibility of Low emissions development Interventions For East African Livestock Sector: Lessons from Kenya and Ethiopia.ILRI Report 46,* Nairobi, Kenya: ILRI.
10. Ettema, F., 2013. *Dairy Development in Kenya,* Netherlands: PUM.
11. FAO, 2010. *Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment ,* Rome: FAO.
12. FAO, 2013. *Climate Smart Agriculture Source Book.* ISBN-978-92-5-107720-7 ed. Rome: FAO.
13. FAO, 2015. *Gender in Climate Smart Agriculture: Module 18 for gender in Agriculture Source book,* Rome: World Bank Group, FAO and IFAD.
14. FAO, 2018. *Africa sustainable Livestock 2050. Livestock Livelihoods Spotlight Kenya(cattle and Poultry sectors),* Nairobi, Kenya: Republic of Kenya, USAID.
15. FAO, 2018. *Global Livestock Environmental Assessment Model Vesrion 2.0 Data reference 2010,* Rome: FAO.
16. FAO & ILRI, 2016. *Smallholder Dairy Methodology: Methodology for GHG Emission Reductions from Smallholder Production System,* Nairobi: FAO, ILRI,MOALF,Gold Standard Foudation.

17. FAO & Newzealand Agricultural Greenhouse Research centre, 2017. *Options for Low Emissions Development in the Kenya Dairy Sector-Reducing Enteric Methane for Food Security Livelihoods,* Rome: 43 pp.

18. Faures, J. M., Bartley, D., Bazza, M. & Hougeveen, J., 2013. *Climate Smart Agriculture Source book.* 557 ed. Rome: FAO.

19. Flysjo, A., 2012. *Green House Gas Emissions in Milk and Dairy Products Chains. Improving the Carbon Foot prints of Dairy Products.* Tjele, Denmark: Department of Agroecology Science and Technology, AARHUS University.

20. Gaiten, L. et al., 2106. Climate Smart Livestock Systems: An assessment of Carbon Stocks and GHG emiisions in Nicaragua. *Peer reviewed,* 11(12), p. 0167949.

21. Gerber, P. J., Henderson , B. & Makker, H. P., 2013. *Animal Production and Health Paper,* Rome: FAO.

22. Gerber, P., Steinfeld, H., Henderson, B. & Opio, C., 2013. *Tackling climate change through Livestock: A global assessment of emissions and mitigation opportunities..* Rome: FAO.

23. Groot, A., Bolt, J., H.s.Jat & M.L.Jat, 2018. Business Models For SMEs as a mechanism for Scaling Climate Smart Technologies; The case of Punjab India. *Journal of Cleaner Production*, 5 November, p. 1119.

24. Grossi, G., Goglio, P., Vitali, A. & Williams, A. W., 2019. Livestock and climate change: impact of livestock on climate and mitigation strategies. *Animal Frontiers,* 9(1), pp. 69-79.

25. Joyce, A. & Paquin, R. L., 2016. The Trippled Layered business Model Canvas: A Tool to Design more Sustainable Business Models. *Journal of Cleaner Production,* Volume 135, pp. 147- 1486.

26. Kashangaki, J. & Ericksen, P., 2018. *Cost-benefit analysis of fodder production as low emission development strategy for the Kenyan dairy sector,* NAIROBI, KENYA: ILRI.

27. Katothya , G., 2017. *Gender assessment of Value Chains: Evidence From Kenya,* Rome: FAO.

28. Kibiego, M. B., Lagat, J. K. & Bebe, B. O., 2015. Competititvenss of Smallholder milk Production Systems in Uasin Gishu County of Kenya. *Journal of Economic and Sustainable Development,* 6(10).

29. Kiiza , A., 2018. *Scaling up Climate Change Mitiagtion Practices in Smallholder Dairy Value Chains: A case study of Githunguri Dairy Farmers Cooperative Society, Kiambu County, Kenya,* Velp. Master Thesis: VHL: Master Thesis.

30. Lardy, G., Stoltenow, C. & Johnson , R., 2008. *Livestock and water.* Fargo, North Dakorta: North Dakorta State university.

31. Long, T. B., Block, V. & Coninx, I., 2016. Barriers to diffussion of Technological Innovations for Climate Smart Agriculture in Europe:Evidence from the Netherlands,France,Switzerlands and Italy.. *Journal of Cleaner Production,* Volume 112, pp. 9-21.

32. Minah , M., Malvido, A. & Carletti, P., 2018. *Pathway to Inclusion: Evidence From Zambia's Subsidy Program and Farmer Organisations..* Berlin: SLE(Centre For Rural Development.

33. Misselbrook, T., Prado del, A. & Chadwick, D., 2013. Opportunities For Reducing Environmental Emissions from Forage Based Dairy farms. *Agricultural Food Science,* 22(1), pp. 93-107.

34. MOALF, 2016. *Climate Risk Profile for Nakuru. Kenya County Climate Risk Profile series,* Nairobi, Kenya: The Kenya Ministry of Agriculture, Livestock and Fisheries.

35. MOALF, 2016. *Kuresoi South Subcounty Annual Report,* Nakuru: County Government of Nakuru.

36. MOALF, 2017. *Kenya Dairy Nationally Appropriate Mitigation Action(NAMA) concept Note. A Proposal for Green Climate Project,* Nairobi: NAMA.

37. MOALF & MOENR, 2017. *Climate- Smart Agriculture Strategy 2017-2026,* Niarobi: Govenrment of the Republic of Kenya.

38. Mooman , W. et al., 2011. *Renewable Energy and Climate Change,* Cambridge United Kingdom and New York, USA: Cambridge university Press.

39. Muthui, J. M., Mshenga, P. M. & Bebe, B. O., 2014. The Influence of Livestock Market Structure conduct and performance on herd Productivity among small holder dairy farmers in Western Kenya. *Journal of Agricultural Economics and Development,* 3(1), pp. 12- 16.

40. Nelson, J., Gambhir, A. & Daukes, N. E., 2014. Solar Power For CO2 Mitigation. *Briefing Paper 11*, January.

41. Onyango, A. A., 2017. *Contribution of Smallholder Ruminant Livestock Farming to Enteric Methane emissions in Lower Nyando in Western Kenya.* Stuttgart,Hohenheim: Hans- Ruthenberg Institute.

42. Oude, J. O., 2001. *Feeding and Care of Livestock. Managing Dryland Resources. A manual for Eastern and Southern Africa,* Nairobi, Kenya: International Institute For Rural reconstruction (IIRR).

43. Ouma, R., Njoroge , L., Romney, D. & Ochungo, P., 2007. *Targeting Dairy Interventions In Kenya; A Guide for Development Planners, research and Extension Workers.* Nairobi, Kenya: SDP/KDDP. 50pp.

44. Rojas- Downing, M. M., Pouyan, A., Harrigan, T. & Wonznicki, S. A., 2017. Climate Change and Livestock Impacts, Adaptation and Mitigation. *Climate Risk Management,* Volume 16, pp. 145-163.

45. Schaller, M. et al., 2017. *Climate Smart Agriculture : Water harvesting,* Berlin: SLE.

46. Shumba, H. S., 2018. *Integrating Climate Smart Agriculture Interventions in Small Holder Dairy Feed Value Chain in Githunguri & Ruiru Sub-county,Kiambu County, Kenya,* Velp: VHL: Master Thesis.

47. Solomon, D., Mungai, C. & Radeny, M., 2017. *Climate- Smart Agriculture(CSA) for Resilient Agriculture, Food security and Inclusive business Growth in East Africa. Conference 'Research Policy: Two peas in Pod: Adialogue for Food Security Impact'.* Wageningen, CCAFS.

48. Tesfahun, B., 2018. *Carbon Foot prints of Milk at Smallholder Dairy Production in Zeway-HawassaMilk Shed, Ethiopia,* Velp: VHL: Masters Thesis.

49. Thornton , P. K., Steeg , J. V. d., Notenbaert, A. & Herrero, M., 2009. The impacts of Climate Change on Livestock Systems in Developing countries. Areview of what We Know and We need to Know. *Agricultural Systems 101*, 1 April, pp. 113- 127.

50. Thornton, P. K. & Herrero, M., 2010. Potential for Reduced Mrthane and Carbon Dioxide Emissions from Livestock and Pasture Management in the Tropics. *Agricultural Sciences,* 17(46), pp. 19667-19672.

51. Thorpe, W. et al., 2000. *Dairy Development in Kenya: Past, Present and Future.* Nairobi, Kenya, ILRI.

52. Toppo, P. & Raj, A., 2018. Role of Agroforestry in Climate Change Mitigation. *Journal of Pharmacology and Phsiochemistry,* 7(2), pp. 241-243.

53. ugyen, P., Vala, A. & Safari, S., 2019. *Climate Smart Dairy Enhancement Programme : Developing high Quality, Innovative and Widely accessible,Diverse Dairy Products of Happy Cow Limited in Nakuru County,Kenya.* Velp: VHL: Internal Document.

54. Van Dijk, S., Tennigekelt, T. & Wilkes, A., 2015. *Climate- Smart Livestock sector Development: The state play in NAMA development working Paper No. 105,* Copen hagen, Denmark: CGIAR Research Program on Climate Change Agriculture and Food Security(CCAFS).

55. Vermerris ed, 2018. *Reader: Business Economics.* Velp: VHL.

56. Waitituh , J. O., 2017. Small holder Dairy Production in Kenya;a review. *Livestock Research for Rural Development,* 29(139).

57. Wakhaure, . R., Ganguly, S. & Praveen , K., 2015. Role of water in Livestock. *The Recent Advances in Academic Science,* 1(1), pp. 56-60.

58. Wangila, C. N., 2018. *Integration of Climate Smart Agriculture in Supporters in Kiambu Dairy Value Chain and In Knowledge Support systems,* Velp: VHL: Masters Thesis.

ANNEX

N_2O Emissions from manure management

I. Direct N_2O emissions from manure management

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

Where:

N2OD(mm) = direct N2O emissions from Manure Management on the farm, kg N2O yr-1

N(T) = number of head of livestock species/category T in the farm

Nex(T)= annual average N excretion per head of species/category T in the farm, kg N animal-1 yr-1 MS (T, S) = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless (40% nitrogen loss –IPCC standard)

EF3(S) = emission factor for direct N2O emissions from manure management system S in the farm, kg N2O-N/kg N in manure management system SS = manure management system

T = species/category of livestock

44/28 = conversion of (N2O-N) (mm) emissions to N2O(mm) emissions

**Factor for default nitrogen excretion rate for dairy cattle for Africa is 0.63 for local breeds and .60 for exotic breeds and the methane conversion factor for the different manure management system.*

II. Indirect N2O emissions from Manure Management -Tier 1

N LOSSES DUE TO VOLATILISATION FROM MANURE MANAGEMENT

$$N_{volatilization-MMS} = \sum_S \left[\sum_T \left[\left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \bullet \left(\frac{Frac_{GasMS}}{100} \right)_{(T,S)} \right] \right]$$

Where:

Volatilization-MMS = amount of manure nitrogen that is lost due to volatilisation of NH_3 and NOx, kg N yr-1

N(T) = number of head of livestock species/category T in the farm

Nex(T)= annual average N excretion per head of species/category T in the farm, kg N animal-1 yr-1 MS (T, S) = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless

FracGasMS = per cent of managed manure nitrogen for livestock category T that volatilises as NH_3 and NOx in the manure management system S, %

III. Emissions from fuel consumption

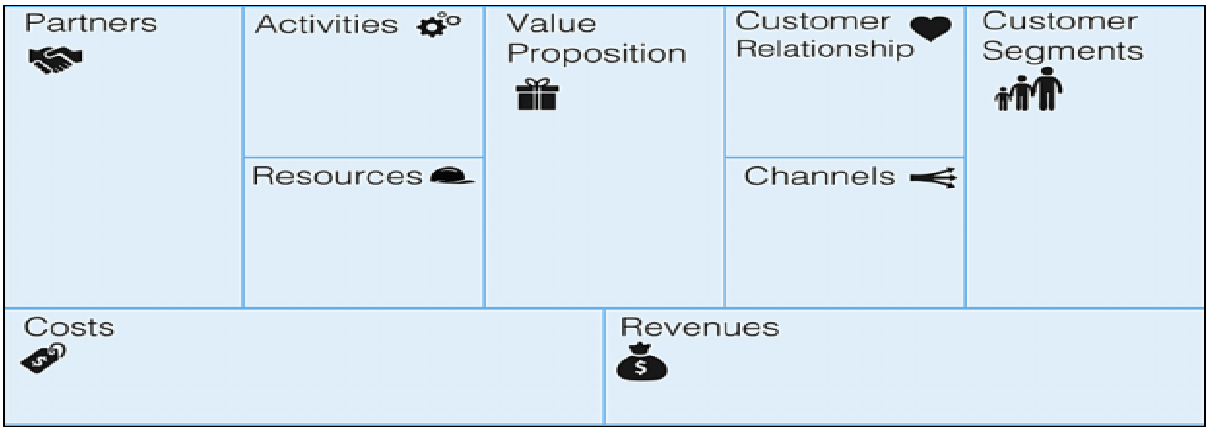
$$E_{fuel} = Fuel_{cons} * EF_{fuel}$$

Where:

- E fuel = emission of a given GHG by type of fuel (kg GHG)
- Fuel cons=amount of fuel combusted (L)
- EF fuel= emission factor of a given GHG by type of fuel (kg gas/L)

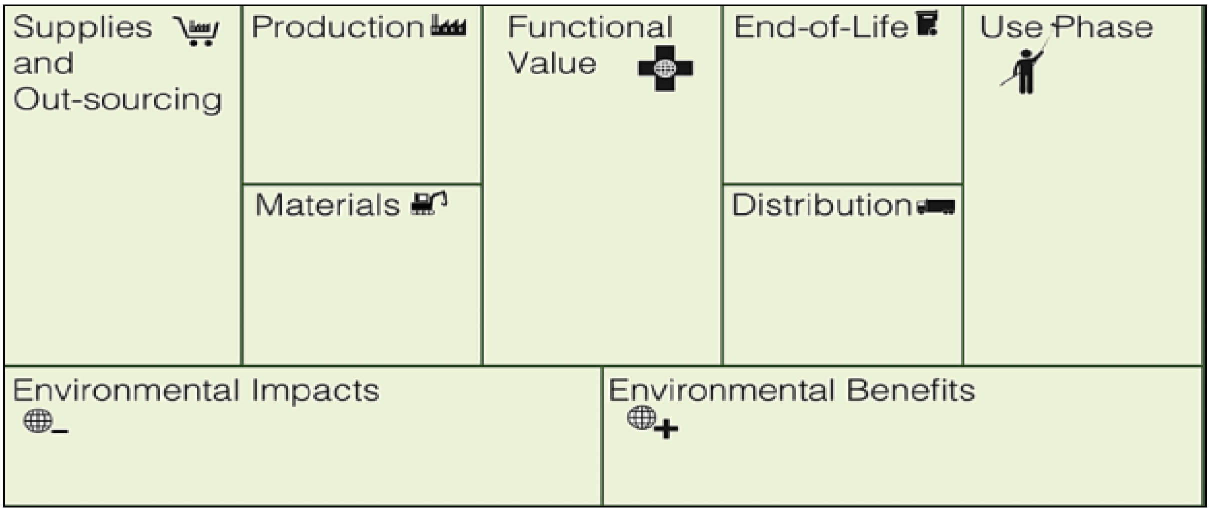
NB: EF (Emission Factor) 2.67kg CO_2/litre for diesel and 2.42 for Gasoline.

Figure 1: Economic business model canvass.



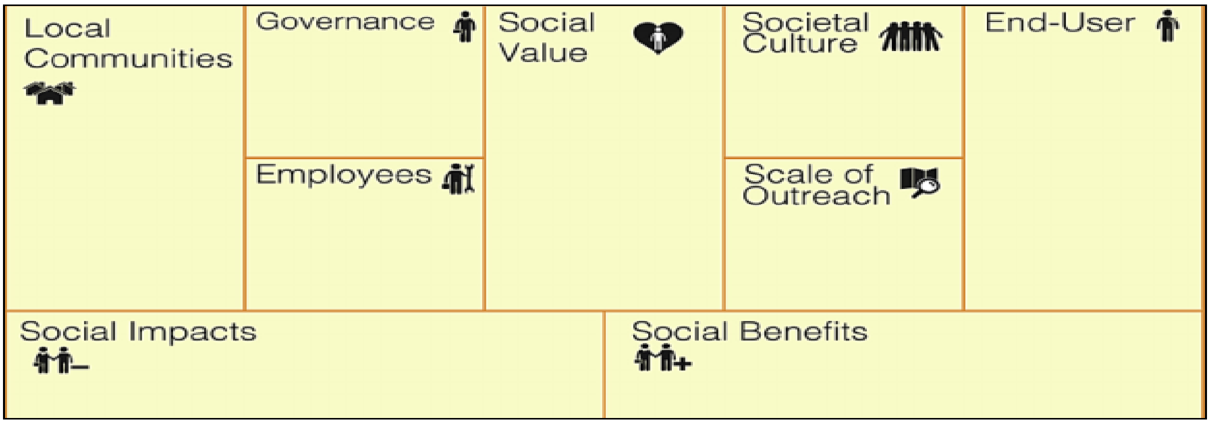
Source: (Joyce & Paquin, 2016).

Figure 2: Environmental Life Cycle Business Model Canvass



Source: (Joyce & Paquin, 2016).

Figure 3: Social Stakeholder Business Model Canvass

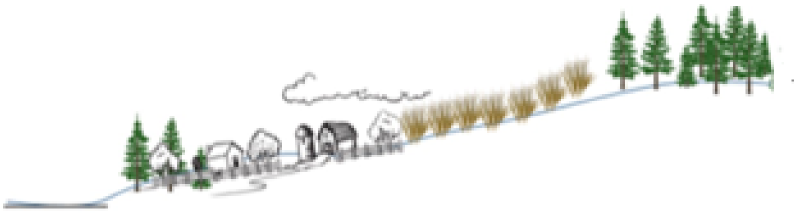


Source: (Joyce & Paquin, 2016).

Figure 4: Transect walk for Olenguruone

	River	forest	Other vegetation	pasture	Zero-grazing unit	homestead	road
Type of soil	Clay soil	Red loam soil					Murram
infrastructure		Foot paths	Natural vegetation and shrubs			Foot pathways	Murram road
Livestock		Birds			Dairy cattle (Friesian, Ayrshire)	Poultry	
Crops			Tea plantation	Napier grass, Nandi Setaria, Oats, Brachiaria, desmodium alfalfa, edible cana, Kikuyu grass,lupins.		Flowers and hedges	
Trees				Olea African Africana,prunus africana Grevillea, blue gum, bamboo, bottle brush	Sesbania-sesban, Lucerne tree, Caliandra	cypress	Tress along the roads
Water source	Streams, seasonal rivers				Rain water, pumped water	Wells, rain water	
challenges	Dry up during dry season		weeds	Weeds, Climate change	Hygiene, drainage, manure storage		Poor weather road,
opportunities	Water availability for irrigation.	Water catchment and climate change mitigation, aesthetic value and ecosystem balance	Soil cover, CO_2 sequestration	Fertile soil Land for expansion, manure from dairy animals	Increase milk production, disease control, biogas production, good husbandry practice		Good road networks

Figure 5: Transect walk for Githunguri



	Roads	Homestead	Farm land	vegetation
Soil type	Murram	Red Loam soil		
Infrastructure	Weather and tarmac roads	Foot path,		
Crops	hedges			Blue gum, grevillea
Livestock		Dairy cattle (Holstein Friesian) and indigenous poultry		
Water source		Boreholes, rain water	Rain water	
Challenges	Inaccessibility during rainy season		Small sizes of land	Lack of expansion
opportunities	Well connected roads	Fertile soil, water availability,	Fertile soil	Soil cover and water conservation

Key informants interview checklist

Activity	Remark
Name of Interview and sex	
Name of institution	
Position of interviewee	
Main task of the institution	
Type of service provided	
Types of training, technologies provided (in which area and for whom)	
How is information and knowledge is transferred	
Who are the partners	
How do you define inclusiveness and resiliency	
How important it is for your institution and farmers	
How technology reaches the farmers	
What type of climate smart dairy information have you provided before	

Questionnaire

Interview checklist

1

Case study number				Date			
Total land size							
Distance from the nearest town							
Sex of farm owner	Male			Female			
Mean winter temperature (ºC)				Agro-ecological zone			
Cooperative membership	Yes			No			

2

Herd module							
Number of animals	Milking cows	Dry cows	Bulls	Heifers	Calves	Calves	Oxen
Average body weight							
Growth rates							
Replacement							
The calving intervals							
Total lactation days							
Age at first calving							
Percentage female that give birth per year							
Method of breeding	A.I		Bulls				
Total number sold							
Total number culled							
Cost of breeding							
Total							

3 **Feed ration & intake module**

Ration composition							
Nutritional values							
Animal energy requirements							
Animal feed intake (Dry matter intake)/day							
Feeding situation	Confined	Grazing	Pasture conditions	Fodder production			
Amount of concentrates per day							
Kg feed fed to the animal per day (is it total mixed ration?)							
Source of feeds if not produced in the farm.							
How the feed is produced in the farm, inputs used	Fertilizer		Pesticides		Herbicides		
Feed digestibility (%)							
Seasonality and its influence on milk production							
Seasonality and its influence on feed availability and cost							
Mode of transport for the transportation of feeds							
Vehicle efficiency							
Distance travelled							
List of feed ingredients and cost	Concentrates				Roughage		Supplements

4

Animal emission module							
Animal nitrogen and volatile solids excretion rate							
Total herds emission from manure			N_2O		CH_4		
Total herds emission from enteric fermentation							

5

Manure module							
Total manure produced per year	Milking cows	Dry cows	Bulls	Heifers	Oxen		
Manure application on pasture							
Manure application on arable land							
Manure storage	Dry storage	Daily spread	Biogas	Solid storage	Compost	Slurry/liquid	Uncovered anaerobic lagoon
Total months per storage system							
Total manure per storage method							
Method of manure application							
Total months per storage system							

6

Feed emission module							
N_20 from applied and deposited manure							
N_20 from fertiliser and crop residues							
CO_2 from field operation							
CO_2 fertiliser production							
CO_2 pesticides production fertiliser production							

CO_2 from feed blending							
CO_2 processing and transport							
CO_2 from land-use change							

7

Allocation module							
Litres of milk produced per day by each animal							
Total milk production							
Fat content in the milk							
Total meat producced							
Meat production per animal		Price of milk				other products	
Milk production per animal		Price of meat					
Manure		Price of manure					
		Price of live animals					

8

Ranking of functions of cattle							
	1	**2**	**3**	**4**	**5**		
Milk							
Meat							
Manure							
Insurance							
Dowry							
Draft power							
Income							

Average amount of work performed per day (hours day-1)							

9

Climate smart practices							
	1	**2**	**3**	**4**	**5**		
Water smartness							
Energy smartness							
Carbon smartness							
Nitrogen smartness							
Weather smartness							
Knowledge smartness							

10

Inclusiveness and resilience							
Fodder conservation methods							
Milk sales channels i.e cooperative, farm gate etc							
Milk records for 1 year i.e up to the period of research study							
Access to finance							
Access to veterinary care and medicines							
Access to markets							
Access to extension service							
	Fodder production	Input sourcing	Daily dairy activities	A.I &Breeding	Transport to collection centre	processing of milk	Retailing
Role of women							
Role of men							

Role of youth							
Ownership of land	Men		Women			Youth	
Any other form of income such as employment /livelihood							
Form of labour	Family			Hired			
Access to innovation and information sharing platforms	Yes			No			
Availability of social safety net	Yes			No			

Economics							
Variable cost							
Fixed cost							
Interest rate							
Inflation							

Figure 6: Researcher weighing a dairy cow

Figure 7: Researcher weighing a calf

Figure 8: calf grazing in a paddock