Cost-benefit analysis and GHG emission in dairy business models: A case study of Shashamane - Ziway milkshed, Ethiopia

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Dedication

To my husband Stanley and my son Mufaro, for putting a smile on my face every day.

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List of acronyms

ATARC	Adami Tulu Agricultural Research Centre
Bo	Manure maximum CH_4 producing capacity
CH_4	Methane
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
CSA	Climate smart agriculture
FAO	Food and agriculture organisation
FPCM	Fat and protein corrected milk
FPR	Farmer Participatory Research
FRG	Farmer research group
GHG	Greenhouse gas
GLEAM	Global Livestock Environmental Assessment Model
GWP	Global warming potential
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
kg CO_2-eq	Kilograms of CO_2 equivalent
LCA	Life cycle assessment
MMS	Manure management system
NAMA	Nationally appropriate mitigation action
N_2O	Nitrous oxide
CCAFS	Climate change, agriculture, and food security
EM	Effective microorganism

Definition of concept

Fat and protein corrected milk (FPCM)
A standard used for comparing milk with different fat and protein contents. It is a means of evaluating milk production of different dairy animals and breeds on a common basis. Cow's milk is corrected for its fat and protein content to a standard of 4 % fat and 3.3% protein.

Greenhouse gas
A greenhouse gas (GHG) is a gas that absorbs and emits radiation within the thermal infrared range; this 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).

CO2-equivalent emission
The amount of CO_2 emissions that would cause the same time-integrated irradiative forcing, over a given time horizon, as an emitted amount of 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. The CO_2 equivalent emission is a standard metric for comparing emissions of different GHGs (IPCC, 4 AR 2007).

Global warming potential
Defined by the Intergovernmental Panel on Climate Change (IPCC) 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 with the same mass of carbon dioxide.

Tier levels
Defined in IPCC (2006), these correspond to a progression from the use of simple equations with default data (Tier 1 emission factors) to country-specific data in more complex national systems (Tier 2 & 3 emission factors). Tiers implicitly progress from least to greatest levels of certainty as a function of methodological complexity, regional specificity of model parameters, spatial resolution and the availability of activity data.

Anaerobic digesters
Equipment where anaerobic digestion is operated; i.e. the process of degradation of organic materials by microorganisms in the absence of oxygen, producing CH_4, CO_2, and other gases as by-products.

Emission intensity (Ei)
Emissions per unit of output, expressed in kg CO_2-eq per unit of output (e.g. kg CO_2-eq per kg of the egg).

Methane conversion factor
The percentage of manure's maximum CH_4-producing capacity that is actually achieved during manure management; i.e. part of organic matter actually converted into CH_4.

Zero-grazing system
A system of feeding cattle or other livestock in which forage is brought to animals that are permanently housed instead of being allowed to graze. It is also sometimes called "cut-and-carry".

Abstract

The research was carried out in Shashamane-Hawassa milkshed to assess the impact of climate smart practices within the dairy farming systems based on the economic and environmental cost (GHG emissions) and benefits in order to advise on new scalable dairy farming practices in inclusive and resilient business models. The research purposefully selected urban and peri-urban farmers in Shashamane-Hawassa milk shed in a case study approach. Key areas in the study were establishing the link between feed supply and dairy farms, economic and environmental cost and benefits from the climate smart practices that have been implemented from cradle to farmgate. Tools for data collection were semi-structured interviews guided by a checklist, systematic observation, focus group discussion and literature review. The input-output system in the dairy farm and the subsystem within the farm were assessed. The triple base canvas business model was used in assessing the current business models in order to come up with new inclusive and resilient climate smart business model. Economic and environmental cost in the dairy farming systems were quantified based on the lifecycle assessment based on IPCC guidelines, triple base canvas business model, cost-benefit analysis and partial budgeting method. Crop residues were the main form of roughage supplemented with concentrates were fed in both regions. The research found that the adoption of climate smart practices varied between farms and regions. The climate smart practices observed include use of high yielding exotic crossbreeds, use of concentrates, AI and zero-grazing units. Storage of large amounts of crop residues was observed in all the farm whilst manure management system was through the separation of dung and urine, anaerobic digester and the solid storage system all year round. Fodder production was observed in two farms whilst the anaerobic digester was observed in four farms. Findings show that enteric emission is a major contributor to on-farm GHG emissions followed by feed manure management system and transport constituting 78% -87%. On-farm emissions are much higher than off-farm emissions. West Arsi had 97.8% and East Showa had 97.2% exotic crossbreeds on the farm with West Arsi having female animals only. The milk yield ranged between 1752-4238 litres per cow whilst enteric emission per litre of FPCM was 1.23-3.49 Kg CO_2 eq. The carbon footprint of milk range between 1.42 and 4.57 Kg CO_2 eq in the best and worst farm before allocation. Allocation of emissions according to food was 0.05-4.4kg CO_2, livelihood 0.01-3.62kg CO_2 eq and economic 1.17-4.4 Kg CO_2 per litre FPCM. Gross margins ranged between negative 2.99 and 14.29 % increase in gross margin ETB per litre. Manure management using the composting and anaerobic digester had significant impact in reducing direct and indirect GHG emissions in comparison with the solid storage system. Based on research findings the commissioner and farmers can make informed choices when selecting climates smart practices knowing the economic and environmental cost and benefits they can achieve whilst creating shared value instead of only focus capturing economic value. To achieve this the role of knowledge and information systems and stakeholder collaborations is fundamental in the adoption, scaling up and scaling out of climate smart dairy practices in order to build inclusive and resilient climate smart business models.

Keywords: Climate smart practice, dairy business models, LCA, partial budgets, inclusive and resilient dairy business model

CHAPTER 1: INTRODUCTION TO CLIMATE CHANGE AND CLIMATE-SMART AGRICULTURE

1.1 Climate change

Global climate change is primarily caused by greenhouse gas (GHG) emissions that contribute to the warming of the atmosphere (IPCC, 2013) and it is threatening food security as a result of its impact on agricultural activities (FAO, 2013). Agriculture has environmental impacts that include land degradation, air and water pollution, and a decline in biodiversity (Bellarby et al., 2013). Globally, the livestock sector contributes 14.5% of greenhouse gas emissions, driving further climate change (Gerber et al., 2013; Rojas-Downing et al., 2017). Climate change affects the livestock sector through its impact on the quality of feed and forage, water availability, animal productivity, and livestock diseases (Zijlstra et al., 2015). High temperatures and dry conditions reduce the concentration of plant water-soluble carbohydrates and nitrogen, therefore, reducing the quality of crops and forage through lignification (Polley et al., 2013). Benchaar et al., (2001) reports that a decrease in forage quality can increase methane emissions per unit of gross energy consumed. Climate change is negatively impacting on agricultural productivity leaving many smallholder farmers vulnerable and food insecure (Lewis, 2018). Livestock can have a positive contribution to food security in production systems that do not use supplementary cereals (Rojas-Downing et al, 2017).

1.2 Climate-smart agriculture (CSA)

CSA is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security in the face of climate change (FAO, 2013). Applying practices with the lowest emission intensity can reduce emissions by 18-30% without reducing overall output (Gerber et al. 2013). The change in climate through rainfall and temperature variability threaten agricultural production whilst increasing the vulnerability of people dependent on agriculture for their livelihood (Lipper et al., 2014). CSA offers a balance between productivity, household food security and environmental preservation through the triple win concept (enhanced productivity, build resilience and carbon sequestration) (FAO, 2013). Through identification of trade-off and synergies among food security, adaptation, and mitigation CSA offers a basis of informing and reorienting farming systems in response to climate change hence reducing the risk of food insecurity (FAO, 2018, Campbell et al., 2014). CSA can be classified under nitrogen smart, energy smart, knowledge smarts, carbon smart, weather smart and water-smart (World Bank and CIAT, 2015). The practices include integrated crop-livestock systems, aquaculture and agroforestry systems, water and nutrient management, perennial pastures, reduced tillage, restoration of degraded lands, manure management systems, efficient use of water, fertilizer, and green energy (Campbell et al., 2014, Lipper et al., 2014).

1.3 Overview of Ethiopian dairy sector based on Hawassa-Ziway milkshed

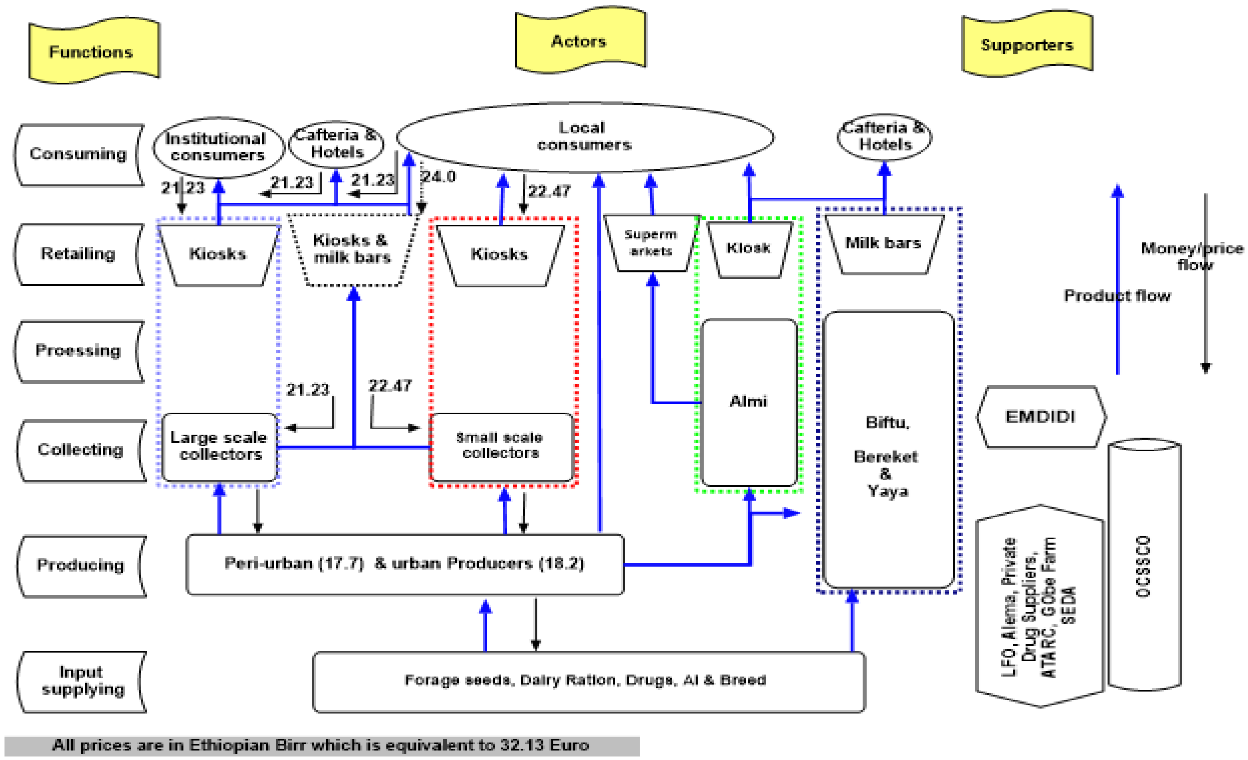
Ethiopia has one of the largest number of livestock in Africa with a cattle population of about 55.2 million cattle (Shapiro et al., 2017). A total of 98.59% of the cattle are local breeds and remaining are hybrid and exotic breeds that accounted for about 1.19% and 0.14% (CSA, 2016). The Ethiopian dairy farming systems can be categorized under five systems of operation; the rural dairy system, which includes pastoral, agro-pastoral and mixed crop-livestock system, contributes 95% of the milk, while the peri-urban and urban including the specialized commercial dairy farms produce only 5% of the total milk production of the country, (Van Geel et al., 2018 and Brasesco et al.,2019). Indigenous stock produces 97% of the milk produced from cattle and the remaining 3% from improved exotic crosses and pure breed cattle. The average daily milk production from the local breed is estimated to be 1.5 to 2 litres (Brandsma et al., 2013), crossbreeds provide 10-15 litres (Van Geel et al., 2018); Tezera, 2018) per day and 20 litres by commercial farmers. Due to low productivity per cow, GHG emissions range between 52.8 kg CO_2 eq/kg FPCM in the pastoral dairy farming system to 2.36 kg CO_2 eq /kg FPCM in commercial farms, showing that the more milk produced per cow the lower the emissions per product (Van Geel et al., 2018). Allocation specified carbon footprint of milk production reduced GHG emissions from 2.07 kg CO_2 eq./ litre to 1.76 kg CO_2 eq./ litre in urban dairy production and from 4.71 kg CO_2 eq./ litre to 3.33 kg CO_2 eq./ litre in peri-urban production in Ziway-Hawassa milkshed (Tesfahun, 2018).

Enteric methane constituted 87% of the total GHG emissions from dairy production (Rojas-Downing et al., 2017). Tesfahun (2018) found that enteric fermentation constituted 80%, feed production 19% and manure management and transport 1% respectively. The factors contributing to high GHG emissions include low yielding local breeds, poor feed quality and limited availability, poor farm management practices (manure management systems), limited fodder growing and preservation capacity (Van Geel et al., 2018 and Tesfahun, 2018). Ethiopia aims to meet the demand for milk nationally and be an exporter of milk by 2020 therefore, there is a need for sustainable intensification of the dairy sector in Ethiopia. The Ethiopian government has implemented a green economy development policy aiming at increasing dairy productivity, reducing GHG-emissions and improving resilience to climate change towards 2030 greening dairy sector and to build a middle-class status by 2025 (De Vries et al., 2016; FRDE,2011).

1.4 NWO GCP-CCAFS 'Climate Smart Dairy in Ethiopia and Kenya' Project

Van Hall Larenstein University of Applied Sciences through the Dairy value chain sustainable agribusiness in metropolitan areas professorships is taking part in NWO GCP-CCAFS 'Climate-smart dairy in Ethiopia and Kenya' project is working on inclusive and resilient climate smart business models in the dairy sector (NWO, 2019). This project is linked to "Nationally Appropriate Mitigation Actions" (NAMA) in scaling up climate-smart agriculture in the dairy sector. Climate Smart Dairy in Ethiopia and Kenya' research project in 2019 was carried out by APCM livestock master students from VHL University of applied sciences. The research project aimed at carrying out an in-depth analysis of dairy farming systems in order to establish the link between GHG emissions and the profitability of different dairy farming systems. Economic and environmental cost and benefits were assessed per climate smart practice implemented. The role of agricultural knowledge and information systems in the scaling up of climate smart practices was researched together with the level of inclusiveness and resilience in the dairy farming system and the dairy value chain. The research has a value chain approach and aims to generate inclusive, resilient business models and identify opportunities for scaling up climate-smart dairy practices in Ethiopia and Kenya. The research generated the value chain map in figure 1.

Figure 1: Dairy value chain map for Hawassa-Ziway milkshed



Source: Tesfahun (2018), Endale (2018), Demlew (2018) and Demeke (2018).

1.5 Problem statement

NWO GCP-CCAFS 'Climate Smart Dairy in Ethiopia and Kenya' project carried out research on inclusive, resilient climate smart strategies that can be scaled up in the dairy sector in Ethiopia. The research carried out by CSDEK, 2018 gave an understanding of the dairy value chain, the dairy farming systems and the climate smart practices implemented together with the respective GHG emissions for various activities in the value chain. Gender roles and the level of inclusiveness in different business models were identified together with the level of inclusiveness. However, the research did not clearly establish the link between GHG emissions and the profitability of the dairy business models and economic and environmental costs that come from each climate smart practice implemented.

1.6 Research Objective

To assess the impact of climate smart practices within the dairy farming systems based on the economic and environmental cost (GHG emissions) and benefits in order to advise the commissioner (VHL) on new scalable dairy farming practices in inclusive and resilient business models.

1.7 Research questions

Main question 1

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

Sub-questions

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

Main question 2

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

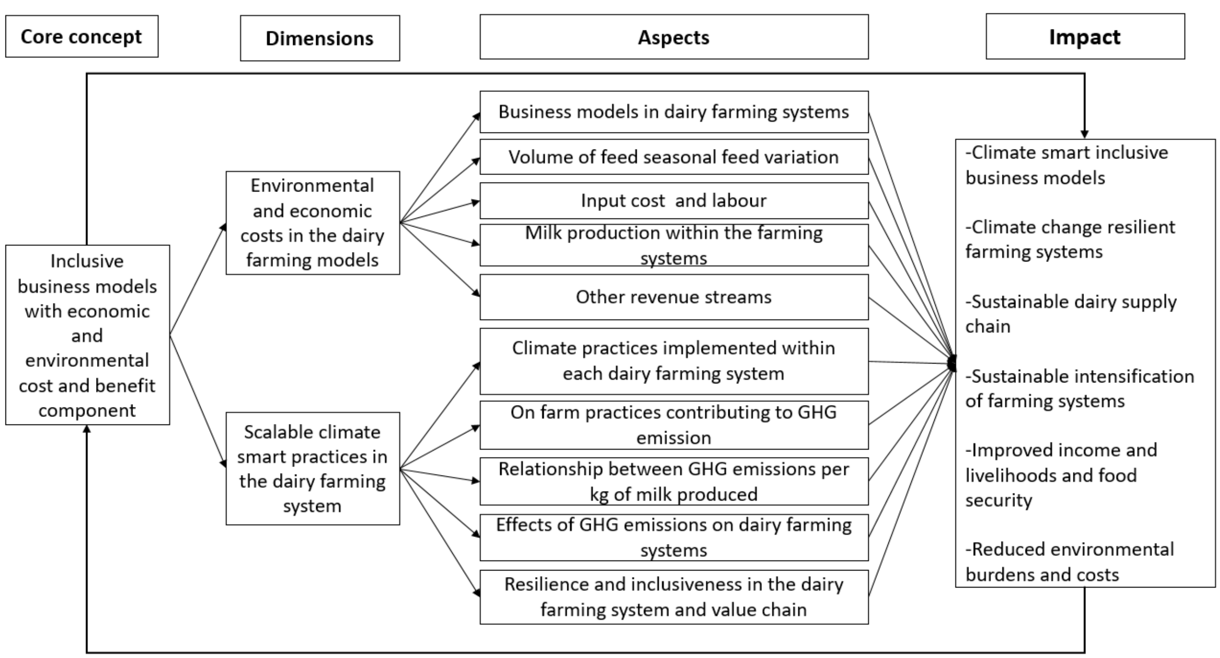
Sub-questions

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 is the level of inclusiveness and resilience in the dairy farming system and value chain?

1.8 Operationalisation of research

The conceptual framework was designed based on Verschuren and Doorewaard, (2010)

Figure 2: Conceptual framework



CHAPTER 2: DAIRY FARMING SYSTEMS, BUSINESS MODELS, COST-BENEFIT ANALYSIS AND LCA

2.1 Dairy farming system

Ethiopian dairy farming systems can be divided into urban, peri-urban and rural systems based on milk shed development pattern that relates to the market and distance from urban centres (Brasesco et al.,2019) or according to agro-ecological zones (Tegegne et al.,2013). Ethiopian dairy systems can be categorized under five systems of operation, pastoral (pastoral livestock farming), agro-pastoral traditional highlands mixed farming), urban and peri-urban (the emerging smallholder dairy farming) and commercial (specialized commercial intensive dairy farming) (Brandsma et al., 2013, Zijlstra et al.,2015, Brasesco et al.,2019, Tesfahun, 2018, Hailemariam, 2018). Smallholder farmers are classified as farmers that own less than 5 or less improved dairy cows and medium level farmers own 6-39 cows and commercial farmers own and above improved dairy cows (Makoni et al.,2013).

2.1.1 The urban milk production system

The urban milk production system is intensive and is mainly found in the highlands and concentrated around Addis Ababa and other regional towns such as Hawassa. The production system is mainly stalling feeding with feed supply being outsourced from the peri-urban and rural areas as the farmers have limited land. Some urban farms are involved in milk production only, but few collect and /or process milk, and sometimes have their own marketing outlet or supply contracts with processors (Brasesco et al.,2019). Urban dairy farming systems have better access to inputs (feed, drugs), markets and service (AI, private extension service) (Tegegne et al., 2013) and productivity is high. The system has 8% exotic breeds, 89% crossbreeds and 3% local breeds and exotic breeds are giving 10-16 litres per day and almost 300 days of the lactation period (Brasesco et al.,2019). Tesfahun, (2018) and Hailemariam, (2018) found milk productivity of 12 litres and it falls within the range. Urban farmers are commercially focused with 73% of the milk being sold, 10% household consumption, 9.4% for feeding the calve and 7.6% is processed at home (Yilma et al., 2011).

2.1.2 The peri-urban milk production system

The peri-urban milk production system practices both intensive and semi-intensive dairy farming. It is practiced within 180km of Addis Ababa radius and 60-80km of other national and regional towns such as Shashimene and Hawassa. The milk producers are commercially oriented with 39% of total milk supplied to Addis Ababa (Brasesco et al.,2019). The peri-urban system has 57% crossbreeds and 43% local breeds and the system is market oriented and generally, the size is smaller compared to rural systems. Together with the urban system, they contribute 10% to the total milk production which goes through the formal channel as a result of their proximity to an urban area. Most farmers depend on the cut and carry system with fodder constituting 44%, brewers waste 35%, oilseed cakes 16%, commercial feeds 3% and the profit margin is about 14% of the sales price. They have better access to services such as AI, feed supply and infrastructure. Access to inputs or services and marketing is mainly through links with processors in urban centres and collective action by producers (Tegegne et al., 2013).

2.1.3 Rural milk production systems

The rural system is characterized by subsistence family farms with low input-low-output system and limited access to formal markets. The system includes the pastoralist (lowlands), agro-pastoralist and mixed crop-livestock farmers mainly in the highlands. Cattle have various functions that include draft power, milk, meat, manure, and hides. The herd structure and composition has more male animals and cows that are kept for security and insurance reasons. The indigenous breeds can only produce between 400-600 litres of milk per cow for lactation of 180-210 days. The systems produce 90% of total milk production and 75% of the commercialized milk in the informal channel (Brasesco et al.,2019). Fragmentation of land holdings is contributing to limited land for fodder production resulting in feed shortages and high dependence on crop residues. Limited availability of forage results in high demand for manufactured feed, which are expensive especially in the dry season (Brasesco et al.,2019). Animal health is generally poor due to high disease prevalence and limited access to veterinary service and drugs and this has affected productivity through high calve mortality (Brasesco et al.,2019).

2.1.4 Commercial animal feed and fodder supply service

Feed supply is a weak link in the Ethiopian dairy value chain, fodder and silage are scarce hence the high prices (Van Geel et al, 2018) limiting the potential of the dairy sector. Specialized fodder farms could be implemented to produce supplementary feed such as grasses and legume fodder options. Some big dairy farms have integrated functions produce their own fodder and process their milk (Zijlstra et al., 2015). Pastures and crop residues are major animal feed resources with most of the grass supply coming from the lowlands. A total of 73% of feed is from natural grazing, 14% crop residue and only 0.2% improved forages leaving 7% deficit in the total dry matter required by the livestock. This presents an opportunity for specialised fodder productions to improve feed resource quality and quantity availability which is necessary for the dairy sector in the area to reach its full productivity potential whilst at the same time creating carbon sinks.

2.2 Farm economics

2.2.1 Cost-benefit analysis

Cost-benefit analysis is a method used to evaluate decisions by comparing the benefit of a farming system and the cost associated with the farming system in order to make business and economic decisions (OECD, 2004). The main purpose is to show that farming system is justifiable and feasible by having benefits that outweigh the cost by attaching monetary values to external effects so that they can be taken into account along with the effects on the ordinary inputs and outputs.

2.2.2 Partial budget

A partial budget is a planning and decision-making framework used to compare the cost and benefits of alternatives faced by a farm business (Economics of precision agriculture, 2002). It highlights how a decision will affect the profitability of the farm for example adoption of new technologies, making capital improvements and changing enterprise or modifying the production practices. A positive net indicates that the farm income will increase as a result of the change whilst a negative indicates a reduction in farm income.

2.2.3 Gross margin

Gross output is the measure of the total value of goods and service produced by a farm in an accounting period. Gross margin is the difference between variable cost (e.g. feed and forage costs, veterinary cost and AI costs) and total revenue (STOAS,1993). Gross margins are useful for detecting weak points in the management of a farm making it ideal for comparing the performance of one enterprise with another

(Vermerris,2013). Gross margins that are less than zero mean the dairy farm is economically inefficient. Using this method, only the variable costs are deducted from the enterprise gross output:

Equation 1: Gross margin

Gross Margin = revenue- total variable Costs.

Variable costs are direct expenses that vary in direct proportion to the quantity of output. Variable cost increase or decrease depending on-farm production volume they rise as production increase and fall as production decreases. The formula for calculating the total variable cost is:

Equation 2: Total variable cost

*Total variable cost = total quantity of output * variable cost per unit of output.*

Fixed costs remain constant regardless of production and these include depreciation, insurance, rent, property taxes, and utilities. Fixed cost are costs that do not change based on production level and it is calculated as follows:

Equation 3: Fixed cost

Fixed cost = total cost –variable cost.

Total costs are the sum of all costs incurred by a firm in producing a certain level of output and it combines fixed costs and variable costs. Total cost is calculated as follows:

Equation 4: Total cost

Total cost = total fixed cost + total variable costs

The dairy farming system has multiple products that bring in revenue, therefore, the economic value of all products will be calculated individually then combined to obtain the total revenue for the dairy farm. Revenue is calculated as follows:

Equation 5: Revenue

Revenue = Price of product total output of product (milk, meat, leather, manure, service)*

Production cost per litre= Total variable cost of production divided by total milk production per year

2.3 Business model

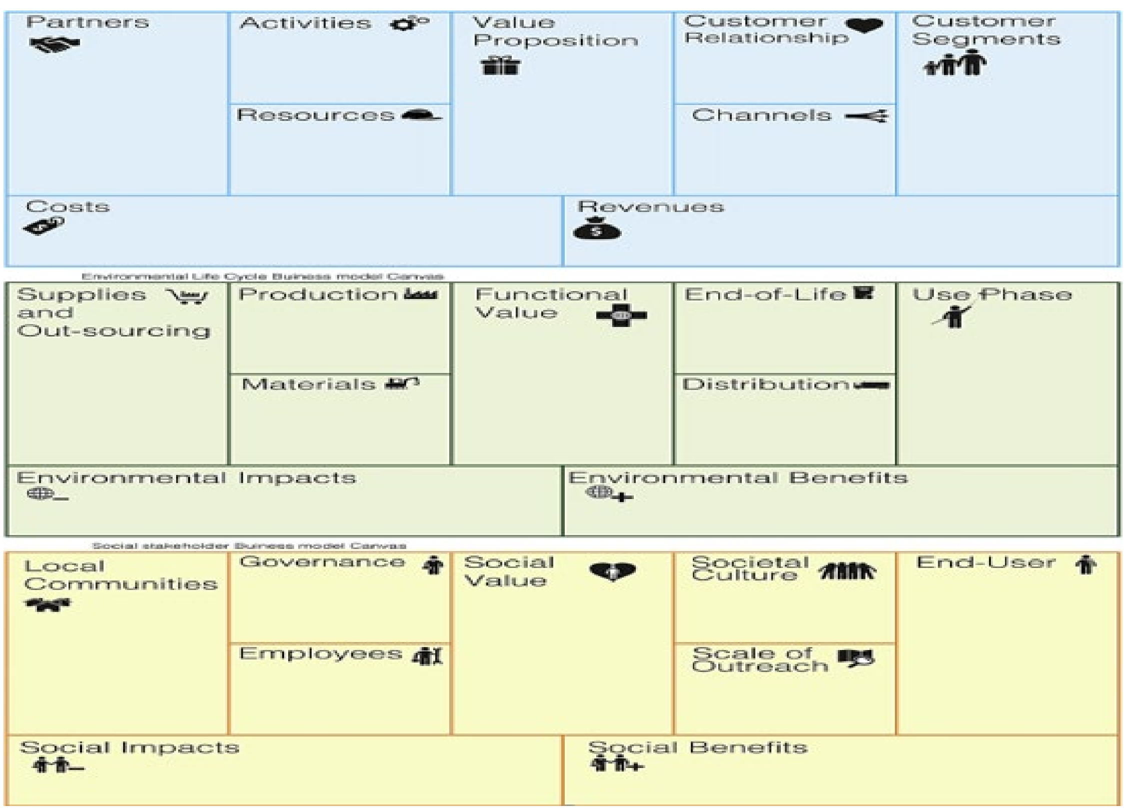
A business model is a configuration of activities and of the organisational units that perform those activities both within and outside the firm designed to create and capture value. Osterwalder and Pigneur, (2010) define a business model as the production and delivery of the specific product to the market and attracts customers to pay for value and converts those payments to profit. The inclusive business model promotes mutual trust and information sharing, which are key parameters in driving business linkages and collaboration, both vertically and horizontally (Rademaker et al., 2015). Boons and Lüdeke-Freund (2013) came up with key elements constituting business models:

1. The value proposition must provide both ecological, social and economic value through offering products and services
2. The infrastructure must be rooted in the principles of sustainable supply chain management
3. The customer interface must enable close relationships with customers and other stakeholders to be able to take responsibility for and manage broader production and consumption systems (instead of selling stuff) and
4. The financial model should distribute economic cost and benefits among the actors involved.

2.3.1 Triple Layer Business Model Canvas

Triple-layer business canvas model is a tool that has been developed from the canvas model by Osterwalder and Pigneur's structured canvas approach to help companies innovate their current business model and form a business model that create, deliver and capture multiple forms of value (Osterwalder and Pigneur, 2010). Joyce and Paquin (2016), developed the triple base business canvas (figure 3) based on the assumption that business model innovation that takes account of the triple bottom line will be more sustainable over time.

Figure 3: Triple Layer Business Model Canvas



Source Joice and Paquin 2016

It can be used as a regeneration, generative and validation tool through addition and balancing of cost versus revenue as well as impacts versus benefits and ensuring a win-win situation for all stakeholders and shareholders. Sustainable business model creates, delivers and captures economic, environmental and social forms of value simultaneously (Joice and Paquin, 2015). This triple-bottom-line approach advocates that organisations should consider the economic, environmental and social impacts of their actions when making decisions, rather than focusing primarily on economic impacts (Savitz, 2012) and considers the needs of all stakeholders and promotes environmental stewardship.

2.4 Life cycle assessment (LCA)

LCA is a tool that can be used to assess the environmental impacts of a product throughout its production chain and disposal (Weiler,2013). LCA provides a framework to broadly identify effective approaches to reduce environmental burdens and evaluate the effect that changes within a production process may have on the overall life-cycle balance of environmental burdens. This enables the identification and exclusion of measures that simply shift environmental problems from one phase of the life cycle to another. The LCA method involves the systematic analysis of production systems, to account for all inputs and outputs associated with a specific product within a defined system boundary (FAO,2010). The system boundary depends on the goal of the study and the reference unit denotes the useful output of the production system and it is based on a defined quality and quantity, for example, a kilogram of fat and protein corrected milk (FPCM) and the indicators are greenhouse gases (CO_2, CH_4, and N_2O) as shown in figure 4. There are challenges in using the LCA tool in agriculture system as a result of agriculture products having multiple outputs accompanied by joint production of by-products. Therefore, there is a need for the partitioning of environmental impacts to each product from the system according to the allocation rule based on economic value product properties (FAO,2010).

Figure 4: Sources of GHG emissions in the dairy farming systems in Ethiopia

Source of emissions		Description
Feed CO_2	field operations	CO_2 emissions arising from the use of fossil fuels during field operations
	fertilizer production	CO_2 emissions from the manufacture and transport of synthetic nitrogenous, phosphate and potash fertilizers
	pesticide production	CO_2 emissions from the manufacture, transport and application of pesticides
	processing and transport	CO_2 generated during the processing of crops for feed and the transport by land and/or sea
	blending and pelleting	CO_2 arising from the blending of concentrate feed
Feed land-use change CO_2	soybean cultivation	CO_2 emission due to LUC associated with the expansion of soybean
	palm kernel cake	CO_2 emission due to LUC associated with the expansion of palm oil plantations
	pasture expansion	CO_2 emission due to LUC associated with the expansion of pastures
Feed N_2O	applied and deposited manure	Direct and indirect N_2O emissions from manure deposited on the fields and used as organic fertilizer
	fertilizer and crop residues	Direct and indirect N_2O emissions from applied synthetic nitrogenous fertilizer and crop residues decomposition
Feed CH_4	Rice production	CH_4 emissions arising from the cultivation of rice used as feed
Enteric fermentation CH_4		CH_4 emissions caused by enteric fermentation
Manure management CH_4		CH_4 emissions arising from manure storage and management
Manure management N_2O		N_2O emissions arising from manure storage and management
Direct energy use CO_2		CO_2 emissions arising from energy use on-farm for ventilation, heating, etc.
Embedded energy use CO_2		CO_2 emissions arising from energy use during the construction of farm buildings and equipment
Postfarm CO_2		CO_2 emissions from the processing and transport of livestock products

Source: FAO (2017)

2.4.1 Emissions from Land use and land-use changes

Changes in demand for feed resources may lead to land-use changes such as deforestation, conversion of native pasture to cropland and this causes the release of GHG into the atmosphere (FAO and ILRI, 2016). Both above and below ground organic matter is oxidized resulting in the release of carbon dioxide and nitrous oxide. Direct land-use change is the conversion of land, which was not previously used for crop production, into land for production of dairy cattle feeds (either through deforestation or the conversion of grasslands to crop production). The emissions caused by the conversion process can be directly linked to the level of demand of dairy cattle feed, and thus allocated to the specific impact of dairy development in the farming system on emission due to land-use change (FAO and ILRI, 2016). Based on the IPCC, (2006) it is assumed that all carbon losses or gains occur during the forest 20 years following a change in land-use change. Maintaining grasslands and permanent pastures are a form of net carbon sink that contributes to reducing the carbon footprint of milk (Bengtsson et al., 2019).

2.4.2 Emission from upstream activities

Upstream emissions are mainly a result of animal feed production (fodder and cereals), processing of stock feeds, energy consumption, and transportation, sources of GHG emissions include the application of manure and artificial nitrogen fertilizers to crops, accounting for both direct and indirect emissions (N_2O and CO_2) (FAO,2010). Nitrous oxide (N_2O) emissions originating mainly from feed production and deposited during grazing represent 24% of the sector's GHG emissions. According to Tesfahun (2018), this contributes 19% of the emissions in the milkshed. Change in land use also during fodder production and pasture development also contribute to GHG emission that was stored in the soil. Global warming potential for CH_4 is 21 and N_2O is 310 CO_2-eq (UNFCC, 2019).

2.4.3 Carbon dioxide emissions from energy consumption

Carbon dioxide is emitted through the milk value chain through energy consumption especially energy produced from fossil fuels. During feed production, energy consumption occurs in the production of fertilizers and the use of machinery for crop management, harvesting, processing, and transportation of produce (Gerber, 2013). Energy is consumed in the dairy farming unit both directly (mechanised operations) and indirectly through the construction of buildings and equipment. Processing, storage, and transportation of dairy products are energy-consuming activities.

2.4.4 Enteric fermentation

Enteric emissions contribute 45 % of the GHG emission in dairy farming systems though it can be higher in extensive dairy systems such as the rural farming system (Rotz and Thomas, 2017) and more than 90 percent of the total CH_4 emissions (Opio et al., 2013). Enteric methane is the main GHG emitted as a by-product of the fermentation of feed by rumen methanogens during the production of volatile fatty acids. Production of enteric methane is influenced by feed type and quality and amount of feed given and is released through the nose and mouth and flatulence. Poor quality forage that has low digestibility increases enteric methane and contribute to low milk production and as a result, the GHG emissions per kg of FPCM is high (Steinfeld et al., 2006). Feeding of high concentrates results in reduced methane because of high digestibility and increase in milk production. Based on findings by Tesfahun, (2018) enteric GHG emissions were high in the rural farming system whilst lowest in a specialized commercial dairy farming system with high yielding exotic breeds and improved, health, feed, and manure management systems.

2.4.5 Emissions from Manure management systems

Manure handling and storage also influence N_2O emissions from manure. Emissions from manure constitute 1% of the emissions in the milkshed together with transport (Tezera,2018). Manure methane emissions are a function of air temperature, moisture, ph, storage time and animal diet (Rojas-Downing et al., 2017). A large proportion of N_2O from manure management is released as direct N_2O, the bulk of which originates from dry systems. Climate smart practices such as the use of anaerobic digester, separation of cow dung and urine and composting can reduce the CH_4 and N_2O emissions (IPCC, 2006). Tesfahun (2018) found limited use of such practices in Oromia. Dry manure storage such as manure deposited on pastures and dung cakes decompose aerobically, therefore, less methane produced as compared to manure stored in lagoons, ponds, and pits that decompose anaerobically (IPCC, 2006). In the peri-urban dairy crop-livestock farming systems in Shashamene-Hawassa milkshed manure is used to fertilize the crop field, (Tegegne et al., 2013) and as fuel more commonly in the peri-urban areas (Tesfahun,2018 and Endale,2018). However, the farmers in the urban dairy farming systems have to pay to dispose of the manure (Nigus et al., 2017 and Tegegne et al., 2013) as use of biogas is not common in the milk shed. Table 1 shows the manure management systems.

Table 1: Manure management system definitions

Manure management system	Description
Pasture/Range/Paddock	The manure from pasture and range animals is allowed to lie as deposited, and is not managed.
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of sufficient amount of bedding material or loss of moisture by evaporation.
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year. It can present natural crusts (formed by the fibrous material contained in the manure) or not.
Uncovered anaerobic lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.
Burned for fuel	The dung and urine are excreted on the fields. The sun dried dung cakes are burned for fuel.
Pit storage	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.
Anaerobic digester	Animal excreta with or without straw are collected and anaerobically digested in a containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by microbial reduction of complex organic compounds into CO_2 and CH_4, which is captured and flared or used as fuel.
Composting – Intensive windrow	Composting (biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production) in windrows with regular (at least daily) turning for mixing and aeration.

Source: IPCC guidelines for national greenhouse gas inventories, 2006.

2.4.6 Functional unit

Dairy cattle production system produces multiple products and services some edible products such as meat and milk and non-edible products such as services, draught power, manure, and capital. The functional units used to report GHG emissions are kg of carbon dioxide equivalent (CO_2-eq) per kg of FPCM. All milk is converted to FPCM with 4% and 3.3% protein, using the formula:

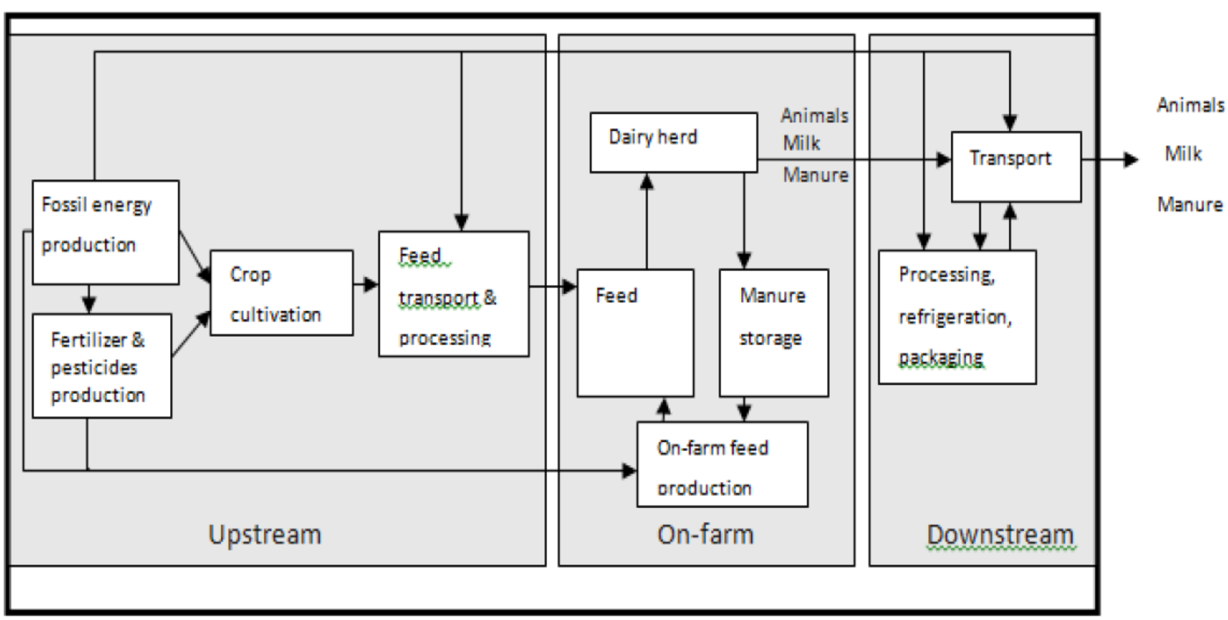
Equation 6: FPCM

FPCM= milk (kg)(.0337+.116*fat content (%)+0.06*protein content (%)* (FAO, 2010).

2.4.7 Systems boundary

LCA systems boundary as shown in figure 5 includes the entire dairy production chain, from feed production to final processing of final product including retail distribution. The system boundary is determined by the goal of the study though it can be split into three section upstream processes (feed production), on-farm activities (dairy farming system) and the downstream activities (processing distribution and retailing). Cradle to farm gate includes all upstream processes in dairy production up to the farm gate where animal products leave the farm gate. Farmgate to retail includes transport of animals and products to processing plants where they are processed into primary products, refrigeration during transport, production of packaging material and transport to the retail distributor (Opio et al.,2013).

Figure 5: LCA systems boundary



Source: De Vries et al.,2016

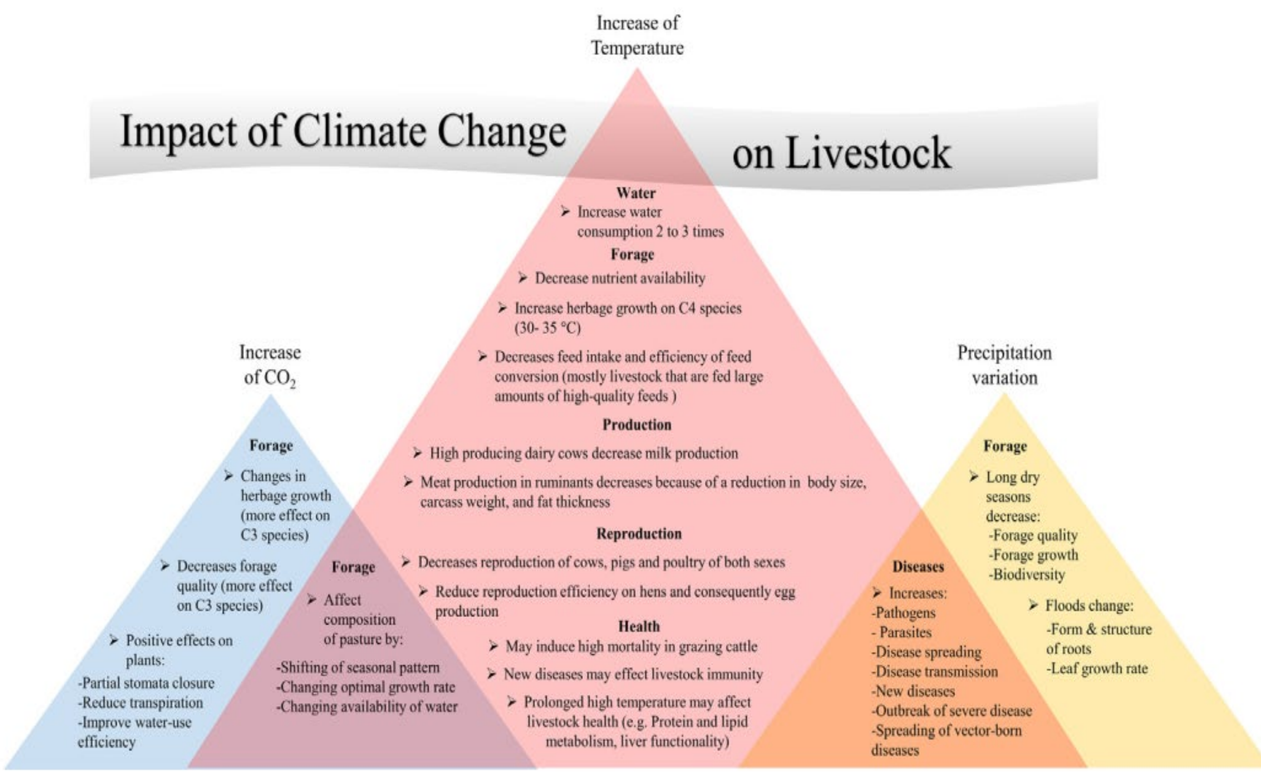
2.4.8 Allocation emissions

Dairy farming has multiple outputs and by-products, therefore, there is a need for the partitioning of environmental impacts to each product from the system according to economic value. The allocation can be done using the attributional approach which estimates the environmental burden of the existing situation under current production and market conditions and allocates impacts to the various co-products of the production system. Dairy cows produce milk, draft power, manure, capital services, and eventually meat when they are slaughtered (Zijlstra et al., 2015). The economic allocation should be done to all products (markets and non-market) that can be economically quantified, that is, milk, manure as fertilizer, cattle as a means of finance and insurance (Weiler et al., 2014).

2.5 Impacts of climate change on livestock

Livestock is affected by climate change through extreme weather patterns that cause stress, shortage of quality feed and pest and diseases as summarised in figure 6.

Figure 6: Summary of impacts of climate change on livestock



Source: Rojas-Downing et al., 2017

2.7 Climate smart practices

2.7.1 At cow level

At cow level, climate smart practices can be implemented by focusing on maximising on feed conversion efficiency. Managing feed conversion efficiency through herd health management, improved fertility, and reproduction coupled with well-formulated feed rations that have high digestibility and meeting the nutritional needs of the cows at various lactation stages reduces methane emission from enteric fermentation (Gerber et al. 2013). Use of AI and improved breeds with high milk yield potential can reduce GHG emission intensity per animal and per kg of FPCM of milk. This will ensure high growth rate, high weaning weights, short age at first calving and short calving interval. Use of concentrate feeds increases milk production and reduce enteric fermentation because of high digestibility. Keeping the calving interval is short as possible is key in improving milk production and increasing the herd size.

2.7.2 Adaptation and mitigation for GHG emission at farm level

Climate smart practices in dairy farming systems can be in the form of mitigation and adaptation measures that contribute towards sustainable intensification and production efficiency of dairy farmings system. On-farm fodder production can minimize emissions during transportation. Improving fodder by including legumes, preservation, and storage such as silage making can improve feed availability which is necessary to ensure sufficient supply of feed all year round. Straw treatment can improve the digestibility of forages which is key in the reduction of enteric methane (Kitaw et al., 2016). Manure management systems such as composting and use of anaerobic digesters can reduce GHG emissions (IPCC, 2006) whilst capturing value through green energy generation and manure as organic fertilizer at the same time reducing the need for artificial fertilizers. The correct application of fertiliser, timing of application and correct placement also reduces GHG emissions. Replacing male animals with females, culling old and low producing cows and replace them with young high yielding exotic and crossbreeds can increase farm productivity. Replacing ox with tractors, bulls replaced by AI with sexed semen and selling of bull calves to pen fattener can reduce overall GHG emission. Improved hygiene practices also give cows an optimum environment for them to produce high quantities of milk and also preventing diseases such as mastitis also observed by Brandsma et al., (2013). Maintaining grasslands and permanent pastures are a form of net carbon sink that contributes to the reduction of dairy sector carbon footprint (Bengtsson et al.,2019).

2.8 Inclusiveness and resilience in dairy farming systems

2.8.1 Inclusiveness

Inclusiveness involves giving equal access and control of opportunities to neglected or excluded stakeholders to influence decision making through negotiation and consensus processes that are transparent and participatory (FAO, 2006). Inclusiveness involves bringing stakeholders together in ways that maximise different resources, skills, and competencies for the definition and achievement of goals. It ensures genuine participation and voice of all concerned stakeholders whilst addressing processes and issues that forge effective multi-stakeholder partnerships for innovation. Making farming systems more ‘inclusive’ means ensuring that all farmers are included as main actors along the value chain. This can be done by facilitating mutually-beneficial linkages with other stakeholders, training leaders, and the installation of good governance models. Access and control of resources such as land, water, and livestock directly influence the level of participation by different sex, age groups, and ethnicities at various levels including decision making. Women, youth and the poor have limited access to resources such as A.I, extension service, water, good infrastructure and financing and this limit their level of participation in dairy farming systems in such areas and this impacts on productivity and income generated from the system. At the farm level, women and the youth have important roles in the sustainable transformation of the dairy sector and poverty alleviation.

2.8.2 Resilience

The ability, capacity, and capability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (IPCC, 2012). Resilience approaches equip farmers to use climate-smart interventions and innovations, use climate information for cropping decisions, diversify livelihoods, link to markets, make agriculture profitable, rehabilitate and restore their environment and influence policymakers. Boka (2017) highlights that resilience comprises the capacity to anticipate, mitigate, adapt to, react to and recover from shocks and stress, effective risk assessment and management strategies. To reduce the impact of a range of risks, farmers use various risk management strategies such as diversification of their livelihood activities, for example, crop-livestock farming system (Wassink, 2016), saving, debt management, membership of marketing cooperatives, control of pests and diseases. Resilience can be built through adoption and implementation of technological innovations and willingness by farmers to change towards a more entrepreneurial production system and adoption of climate smart dairy practices and spreading risks. Linkages with necessary stakeholders such as agriculture knowledge and information systems, finance, processors, input suppliers, social security and retailers can improve the resilience of farmers to shocks in the markets and present opportunities for diversification of business model.

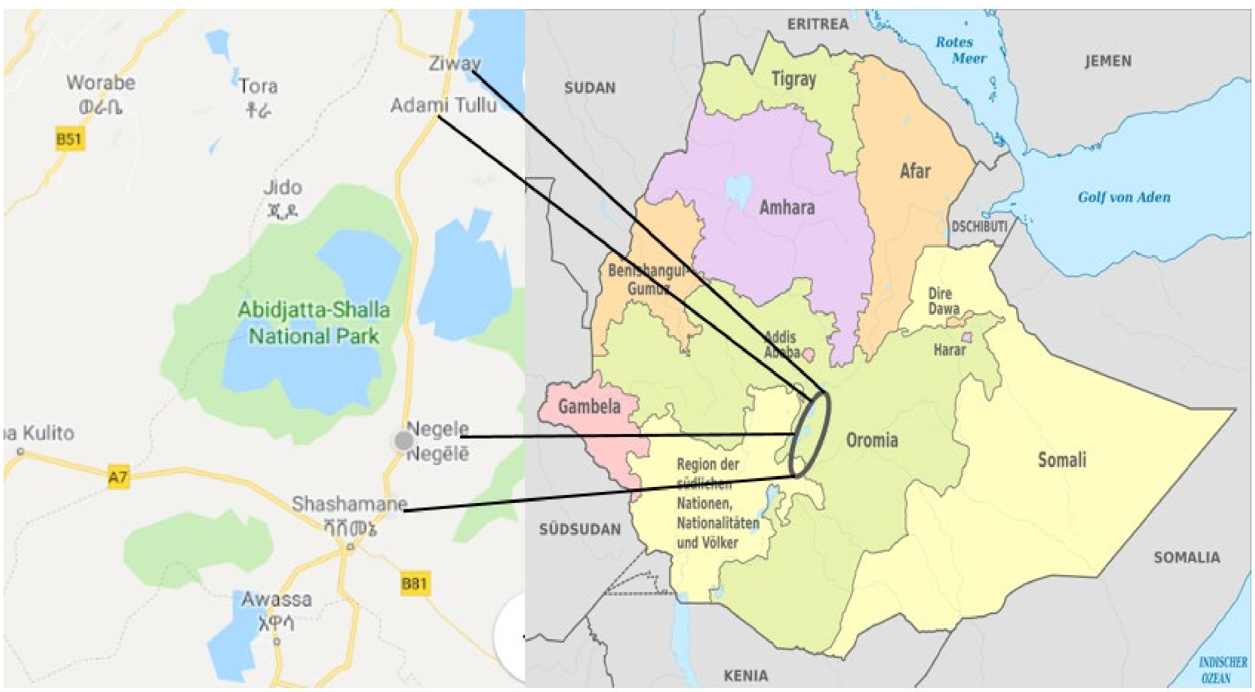
CHAPTER 3: METHODOLOGY

This chapter outlines detailed information on the study area, research design, tools used during data collection and analysis. Equations used for all calculations are also given.

3.0 Study area description

The research was carried out in East Showa and West-Arsi, in Oromia and the case studies were selected from Ziway, Shashamane, Arsi Negele, and Adami Tulu milkshed. The milkshed is located south of Addis Ababa in the central Great rift valley with an altitude ranging between 1500-2600 metres above sea level and temperature ranges between 12-27°C and receives annual rainfall ranging from 837mm in Ziway in the north to over 1057mm in Shashamane. The highlands area is characterized by a bimodal rainfall pattern with a mean average rainfall of 900-1000mm per year (Brasesco et al.,2019). The agro-ecology ranges between lowland and midland. Small and medium farmer dominate in the area and the majority of the farmers (67%) have a mixed livestock-crop setup with home processing for milk.

Figure 7: Research area



Source: Google map, 2019

3.1 Research units and sampling method

The case study approach was used in this research in order to carry out an in-depth analysis of the dairy farming systems and climate smart practices implemented their effect on profitability and GHG emissions. A total of six farms with different dairy farming systems and one specialized fodder farm farms were supposed to be part of the research. However, a specialized fodder farm could not be found therefore it was replaced by a dairy farm with fodder production. These farms were identified with the help of a key informant 3 from Adami Tulu research centre. The location and category of research units are shown in table 2.

Table 2: Research units

Region	Urban (Without land for fodder production)	Urban farmer (with land for fodder production)	Peri-urban
West Arsi	West Arsi 3	West Arsi 1	West Arsi 2
East Showa	East Showa 3	East Showa 2	
	East Showa 1		
	East Showa 4		
Total	4	2	1

Research approach

The researcher had support from study partners working on the same topic and Kenya and during fieldwork. The researcher was also working in a team with the students who worked on the initial research that gave an overview of the dairy sector in the study area and also the second group of students who were carrying out an in-depth study of the dairy farming systems and the role of agriculture knowledge and information systems. In order to get in-depth information, a total of 2-4 days was spent observing and collecting data at each farm. The LCA model was used as a guide in data collection checklist and GHG quantification by taking into account all emission from cradle to the farm gate based on IPCC (2006) guidelines.

3.2 Research boundaries and functional unit

The research focused on the upstream and on-farm assessment of all input-output activities from cradle to farm gate. The analysis focused on dairy farming systems and the subsystems within the farm based on the input-output connections and, how they influence GHG emissions and profitability per climate smart practice implemented. Both on-farm (manure management system, enteric fermentation) and off-farm emissions (fossil fuel energy generation, emissions during crop production, transport, land use, and land-use changes) were considered in comparison with the gross margins, partial budget, and cost-benefit analysis. Based on Weiler et al., (2014) the multi-functionality of dairy animals was considered from an economic, food and livelihood perspective in the allocation of GHG emissions. Other environmental impacts of dairy farming in the urban and peri-urban farming system were considered. Although home processing of milk was considered an on-farm activity, none was observed in this study.

Production performance

Farm production performance was measured by milk yield per cow, calving interval, lactation days, age at first calving, lactation length and this was based on the information given by the farmer and it was verified by going through farm record where possible. The number of cows that calve per year and the number of calves on the farm were used to verify the calving interval. The equations below were used to calculate production performance.

Equation 7: Dairy farm production performance

*Lactation length /year = lactation days*365/calving interval(in days)*
*Kg milk per year=milk production per lactation*365/calving interval (in days)*
*Peak lactation =avarage production*1.7*
Average production per day (lactation days)=kg milk per year/365

Quantification of GHG emissions

The quantification of GHG emissions was carried out done based on IPCC, (2006) formulas and guidelines

a) Feed production

The total yield of both forage and crop residues was calculated by multiplying yield per hectare by the number of hectares cultivated for both on-farm and off-farm feed production.

Equation 8: Total yield

*Total yield= yield per hectare*number of hectares cultivated* number of cropping*

Where:

- Total yield= the overall amount of crop yield per Hecate per year
- Yield per hectare= total amount of crop harvested per hectare
- Number of cropping = the number of time the crop is grown on the same land per year.

Value of crop was calculated by multiplying total yield by the price

Equation 9: Value of crop

*Value of crop= total yield * price*

Where:

- Total yield = actual amount of yield harvested per year
- Price= the average market price offered on the market

Emissions from fertilizer

Direct emissions

Direct emissions from crop production were quantified by direct emissions of N_2O from synthetic and organic fertiliser application through nitrification and denitrification processes. This was done based on IPCC (2006) Tier 2 guideline to quantify direct N_2O emissions from fertilizer application on managed soils during feed production.

Equation 10: Direct N_2O emissions from fertiliser application

$$N_2O_{\_ND} = N_2O_{inputs}$$
$$N_2O_{inputs} = [[(F_{SN} + F_{ON}) * EF_1]]$$

The conversions of N_2O-N emissions to N_2O emissions was performed by using the following equation:

Equation 11: Conversion of N_2O-N to N_2O

$$N_2O = N_2O\text{-}N*44/28$$

Where:

- N_2O_ND= annual direct N_2O-N emissions produced from managed soils, kg N_2O-N per year
- N_2O inputs=annual direct N_2O-N emissions from N inputs to managed soils, kg N_2O-N per year
- F_{SN}=annual amount of synthetic fertiliser N applied to soils, kg N per year
- FON=annual amount of organic fertiliser N applied to soils, kg N per year
- EF1= emission factor for N_2O emissions from N inputs, kg N_2O-N per kg N input

Indirect emissions

Indirect emissions result in nitrogen losses that occur in the forms of ammonia and NO_X through volatilization and leaching.

Volatilization, N_2O

The following formula was used to estimate the amount of N_2O deposition on N from well-managed soils

Equation 12: N_2O volatilization

$$\mathbf{N_2O_{(ADT)\_N}} = \left[\left(F_{SN} * Frac_{(GASF)}\right) + \left(F_{ON} * Frac_{(GASM)}\right)\right] * EF_4$$

Where:

- N_2O (ATD)-N= annual amount of N_2O-N produced from atmospheric deposition of N volatilized from managed soils, kg N_2O-N per year,
- FSN= annual amount of synthetic fertiliser N applied to soils, kg N per year
- FON=annual amount of organic fertiliser N applied to soils, kgs N per year
- FracGASF= Fraction of synthetic fertiliser N that volatilizes as NH_3 and NO_X, kg Nvolatilised per (kg of N applied)
- FracGASM= fraction of organic fertiliser N that volatilises as NH_3 and NO_X, kg N volatilized
- EF4=emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, [kg N-N_2O per (kg NH_3-N+NO_X volatilized)]

Conversion of N_2O(ATD)-N emissions to N_2O emissions to N_2O emissions for reporting purposes was performed by using the following equation:

Equation 13: Conversion of $N_2O_{(ADT)}$

$$\boldsymbol{N_2O_{(ADT)}} = N_2O_{(ADT)\_N} * \frac{44}{28}$$

Leaching/ runoff $N_20(L)$

The following equation was used in the estimation of N_2O lost due to leaching

Equation 14: Leaching

$$N_2O_{(L)\_N} = (F_{SN} + F_{ON}) * Frac_{LEACH\_(H)} * EF_5$$

Where:

- N_2O(L)-N= annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils, kg N_2O-N per year
- FSN=annual amount of synthetic fertiliser N applied to soils in, kg N per year
- FON= annual amount of organic fertiliser N applied to soils, kg N per year
- FracLEACH-(H)= fraction of all N added to mineralised in managed that is lost through leaching and runoff, (kg N additions)
- EF5=emission factor for N_20 emissions from N leaching and runoff, kg N_2O-n (kg N leached and runoff)

Conversion of N_2O(L)-N emissions to N_2O emissions was carried using the equation:

Equation 15: Conversion of N_2O(L)-N emissions to N_2O emissions

$$N_2O_{(L)} = N_2O_{(L)\_N} * \frac{44}{28}$$

b) Emissions from farm machinery and feed transport

Use of machinery contributes to the GHG emission during feed production through ploughing of the land and harvesting. Combustion of fuel by machines result in CO_2 emissions. Emissions during feed production (ploughing and harvesting) and transportation were calculated based on the type of transport used, distance travelled, the quantity of fuel consumed per trip and the frequency of the trips. Based on the diesel-powered Isuzu vehicle observed and emission factor of 2.67kg CO_2/litre (Gabre,2016) was used in the quantification of GHG emissions. Allocation of fuel was considered based on information from key informant 2 the fuel consumed was allocated to different feeds in the truck. The quantification of GHG emissions was carried out based on IPCC guideline as shown in the equation below:

Equation 16: 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)

*the emission factor of 2.67kg CO_2/litre according to Gabre (2016) was used for the diesel truck that was observed during fieldwork.

c) Enteric emissions

Methane emissions from enteric fermentation were estimated based on IPCC Tier 2 approach since enteric emissions are a major problem in the study area especially as a result of the rations that are dominated by crop residues. The herd structure was considered in order to come up with the different cohorts in the herd, ration given and the quantity of feed allocated per cohort. The main cohorts identified were based on breed then subdivided into milking cows, dry cows, pregnant cows, heifers, calved, bulls and oxen.the average daily feed intake was estimated based on observation and information given by the farmers then adjusted for dry matter according to literature.

Herd size

Based on IPCC (2006) the number of animals per farm was kept constant as the number of animals sold was replaced by the calves calved per year. Therefore, no growth in herd size was captured as shown in table 3. Total milking cows consist of dry cows, pregnant cows, and cows in milk. The formula given below was used to calculate annual herd size.

$$AAP = Days\_alive \bullet \left(\frac{NAPA}{365} \right)$$

Where:

- APP: annual average population
- NAPA: number of animals produced annually

Equation 17: Gross energy

$$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_1 + NE_{work} + NE_p}{REM} \right) + \left(\frac{NE_g + NE_{wool}}{REG} \right)}{\frac{DE\%}{100}} \right]$$

Where:

- GE= gross energy, MJ day-1
- NEm=net energy required by the animal for maintenance, MJ day-1
- NEa= net energy for animal activity, MJ day-1
- NEl= net energy for lactation, MJ-1
- NEwork= net energy for work, MJ-1
- Nep = net energy required for pregnancy, MJ-1
- REM= ratio of net energy available in a diet for maintenance to digestible energy consumed
- NEg= net energy needed for growth, MJ day-1
- REG= ratio of net energy available for growth in a diet to digestible energy consumed
- DE%= digestible energy expressed as a percentage of gross energy
- Methane conversion factor Ym for cattle fed low-quality crop residues and byproducts of 6.5% was used in this study according to IPCC (2006) guidelines.

Equation 18: CH_4 emission factors for enteric fermentation from a livestock category

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

Where:

- EF = emission factor, kg CH_4 head-1 yr-1
- GE = gross energy intake, MJ head-1 day-1
- Ym = methane conversion factor, percent of gross energy in feed converted to methane
- The factor 55.65 (MJ/kg CH_4) is the energy content of methane

The total methane emission can be computed by multiplying the number of animals in each category by the emission factor as shown below.

Equation 19: Total enteric emissions

$$Emissions = EF * (N_T)$$

$$Total\ CH_{4enteric} = \sum_i E_i$$

Where:

- Emissions= enteric methane emissions, Kg CH_4 per year
- EF=emission factor for the defined livestock population, kg CH_4 per head per year
- NT= the number of heads of cattle/ category
- T= species /category of livestock
- Total CH_4 enteric= total methane emissions from enteric fermentation, Kg CH_4 per year
- Ei=is the emissions for the ith cattle categories and subcategories

d) Manure management

Methane (CH_4)

Methane emission from manure management can be calculated by using the following equation 20 as indicated by IPCC, (2006) guidelines.

Equation 20: CH_4 from manure management

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

Where:

- CH_4 manure = CH_4 emission from manure management, for a defined population, Gg CH_4 year-1
- EF(T)= emissions factor for the defined livestock population, kg CH_4 head-1 (dairy=46 and other cattle =31)
- N(T)= the number of head of livestock species/ category T in the country
- T= species/ category of livestock

The manure management system Tier 2 of IPCC was used in the characterisation of the manure management system and methane conversion factors in order to come up with the emissions. Manure characterisation involved quantifying the volatile solids and excretion rates (VSE) in the manure and the maximum amount of methane that can be generated from the manure (Bo). Annual manure production was estimated based on the animal dry matter intake, digestibility of the ration and the number of animals on the farm.

Equation 21: Volatile solid excretion (VSE)

$$VS = \left[GE * \left(1 - \frac{DE\%}{100}\right) + (UE * GE)\right] * \left[\left(\frac{1 - Ash}{18.45}\right)\right]$$

Where:

- VS=volatile solid excretion per day on a dry-organic matter basis, kg VS per day
- GE=gross energy intake, MJ per day
- DE%= digestibility of the feed in percentage
- (UE*GE) = urinary energy expressed as a fraction of gross energy
- ASH= the ash content of manure calculated as a fraction of the dry matter feed intake
- 18.45= conversion factor for dietary GE per kg of dry matter (MJ per kg)

Manure management system involved identifying the manure management system on the farm then select the appropriate methane conversion factor for that system then calculate the maximum amount of methane that can be generated from the manure (Bo). Methane emission varies with the retention time and temperature during manure storage, therefore, it is important to take note of the temperature variation with seasonals and how the influence methane emission in the storage system. In this study, the default value of 0.1 of methane-producing capacity from manure was used based on IPCC guidelines. The following equation was used in the quantification of methane-based on IPCC tier 2 guidelines.

Equation 22: Methane production from manure management

$$\boldsymbol{EF_T} = (VS_T * 365)\left[B_{o(T)} * 0.67\, {}^{kg}/_{m^3} * \sum_{s,k} \frac{MCF_{s,k}}{100} * MS_{(T,S,K)}\right]$$

Where:

- EF(T)= annual CH_4 emission factor for livestock category T, kg CH_4 per animal per year
- VS(T)= daily volatile solid excreted for livestock category T, Kg dry matter/LU per year
- 365= basis for calculating annual VS production, days per year
- 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 cattle manure handled using manure management system

N_2O emissions

Direct N_2O emission occurs through nitrification and denitrification of nitrogen contained in the manure. The emissions of N_2O from manure management during storage and treatment depends on the nitrogen and carbon content of manure and on the duration of storage and type of treatment. Nitrification of ammonia in the manure takes place when there is sufficient oxygen. Nitrites and nitrates are transformed into N_2O and dinitrogen during the denitrification process when anaerobic conditions prevail (IPCC, 2006).

Equation 23: 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:

- N_2O (mm)= direct N_2O emissions from manure management the farm, kg N_2O year-1
- N(T)= number of head of livestock species/category T in the farm
- Nex (T)=annual average N excretion per herd of species/category T in the farm, kg N animal-1 year-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
- EF_3(S)= Emissions factor for direct N_2O emissions from manure management system S in the farm, kg N_2O-N/kg N in manure management system SS= manure management system
- T= species/ category of livestock
- 44/28= conversion of (N_2O-N) (mm) emission to N_20 (mm) emissions

Indirect emissions

Indirect emissions are a result of volatile nitrogen losses in the form of ammonia and NO_X and the process is influenced by on time and temperature though to a lesser extent. This causes loss of nitrogen to the surrounding air through volatilisation and other losses are through leaching and runoff especially from outdoor solid storage of manure.

Equation 24: 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:

- N 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 = percent of managed manure nitrogen for livestock category T that volatilises as NH3 and NOx in the manure management system S, %

Equation 25: Indirect N_2O emissions due to leaching from manure management

$$N_2O_{L(mm)} = \left(N_{leaching-MMS} \bullet EF_5 \right) \bullet \frac{44}{28}$$

Where:

N_2OL(mm)= indirect N_2O emissions due to leaching and runoff from manure management in the country, kg N_2Oyear-1

- EF5= emission factor for N_2O emissions from emission from nitrogen leaching and runoff, kg N_2O=N/kg N leached and runoff) default value of 0.0075kg N_2O-N (kg N leaching/runoff)-1

Equation 18: Manure nitrogen that leached from manure management systems

$$N_{leaching-MMS} = \sum_{S}\left[\sum_{T}\left[\left(N_{(T)} * Nex_{(T)} * MS_{(T,S)} * \left(\frac{Frac_{leachMS}}{100}\right)_{(T,S)}\right)\right]\right]$$

Where

- N leaching-MMS= amount of manure nitrogen that leached from manure management systems, kg N per year
- N(T)= annual average N excretion per head of cattle /category T
- Nex (T) = annual average N excretion per head of species/category T kg N per animal per year
- MS (T, S) = fraction of total annual nitrogen excretion for each cattle/category T that is managed in manure management systems S, dimensionless
- FracleachMS= percentage of managed manure nitrogen losses for livestock category T due to runoff and leaching during solid and liquid storage of manure

Allocation of emissions

As a result of cattle having many function GHG emissions were also allocated according to the economic value of each function (Weiler et al., 2014). In this study product that has a direct market value were captured according to the market value of annual production. There was no value for manure since the was no market for it so the opportunity cost of using manure as a fertilizer was captured at current fertilizer application rates and prices per hectare. The value of draft power was also captured as the opportunity cost of hiring a tractor.

Equation 26: Value of inputs and outputs

- *Economic value of milk: Value of milk = milk output*milk price*
- *Draft power: Opportunity cost of hiring a tractor to do the same work*
- *Value of live animal sales: Value of live animals sales = head *price*
- *Manure = fertiliser price * N in manure*

Manure application rates were based on estimates based on information from key informant 1 and the nitrogen content in the manure is 1.4% (Weiler et al., 2014).

3.3 Methods of data collection

Data collection consisted of interviews guided by a checklist, systematic observation, photographs and a focus group discussion and validation workshop at the end of data collection. With farmer participation ranking of functions of dairy cows, mapping of the input-output systems at cow level and at farm level. Pictures were taken to retain observed facts and climate smart practices that have been implemented. Both qualitative and quantitative data was collected for the study and data collected was triangulated between different research tools and multiple sources within the same farm and between farms. The following data collection tools were used in the data collection process.

3.3.1 Desk Research

Secondary sources of information were reviewed through the desk research process. This process gave the researcher insight into the context of the research area and familiarize with the research topic and study area. The process enabled the definition of the research problem and what other researchers found within the research area. Sector analysis and value chain mapping were carried out at this stage. Desk research was carried out through internet searches such as Greeni, google scholar, books, publications, and journals.

3.3.2 Systematic Observation

Systematic observations were used as a data collection tool during the transect walk in all seven case study farms to identify the climate smart practices that have been implemented in each dairy farm system and fodder production. The researcher together with the farmer carried out the transect walk where photographs were taken, questions asked and notes where taken. The information from observation was used to complement outcomes from primary and secondary data sources. The observation also generated new interview dimensions, gave the researcher an overview of the farming system and offer clarity to some of the information that was obtained during the interview. Observations were used to find out the interrelationship between sub-systems within the farming system.

3.3.3 Interviews (both Structured and non-structured)

Interviews guided by a checklist were carried out on the 7 research units to collect both quantitative and qualitative data. All interviews were carried out at the farm and at least two people involved in the dairy farming activities were interviewed as a way of generating in-depth information and triangulation of findings between sources. All interviews were guided by a checklist (see annex) to ensure all research areas and questions have been answered. Each interview took about an hour, with follow up questions being done on every other visit to fill gaps or clarification of information given before. Based on information from the interview and observation feed suppliers were tracked and interviewed. However, when a direct connection with the feed supply could not be established an interview with a crop expert and feed agents/traders were added in order to find out the fertiliser application rates and machinery used during crop production. Interview with an animal health expert to have more information on disease prevalence and feed agents to establish feed sources and mode of transport used to transport the feeds. Notes were taken during the interview and transect walk. The interviews were carried out by the researcher with the help of a translator. One person (farmer, wife, child, and farmhand) was interviewed at a time. Interviews with key informant 1 (crop expert), key informant 2 (feed agent and feed traders at the market) and key informant 3 (animal health specialist) were carried out to verify concepts and clarification of specific areas.

3.3.4 Focus group discussion

Two focus group discussions with the research participants were carried out at the end of the research to communicate findings, discuss and validate the findings. The first focus group discussion was carried out at Adami Tulu Agricultural Research centre with East Showa farmers and West Arsi focus group discussion was carried out in Shashamane. The focus group discussions were carried out by my translator who is a researcher at Adami Tulu research centre. This focus group discussion was used as an opportunity to discuss and verify, validate the research findings, triangulate findings between sources and tools, come up with the new business model. The triple base canvas business model was used as a bottom-up approach way of making the farmers involved and maximizing their interest in finding solutions and taking part in the research instead of the researcher coming up with the canvas model.

3.4 Data analysis

Qualitative data analysis was carried out using the grounded theory in transcribing the interviews and extracting quantitative data which was recorded on excel sheets. The transcription of interviews with the farmers was made and organized into relevant topics and then selection of finding categories in relation to the research questions was made. Quantitative data analysis of the economic and environmental cost was carried out to assess farm profitability, partial budgeting, and cost-benefit analysis. Partial budgeting will be carried out to compare the economic and environmental cost and benefit of adopting different climate smart practices and change in the production system such as the use of AI, investing in an anaerobic biogas digester and adoption of exotic crossbreeds. Triple base Canvas business model by Joice and Paquin, (2016) was used to map the current and proposed improved model based on research findings. The attributional life cycle assessment method was used to allocate GHG emissions to various multifunction of the dairy herd.

Quantitative data analysis involved quantification of GHG emissions in the farming systems was carried out using the Life cycle analysis (LCA). GHG emissions from livestock and manure management guidelines of IPCC (2006) tier 1 and 2 together with the excel table designed by Tesfahun (2018) systems were used to quantify the upstream and on-farm GHG emissions. Enteric methane emissions were quantified using IPCC Tier 2 main was used to define animal productivity and GHG emissions based on dry matter intakes. Equations for GHG calculations based on IPCC (2006) chapter 10 and 11 emissions from livestock and manure management and N_2O and CO_2 emissions during feed production.

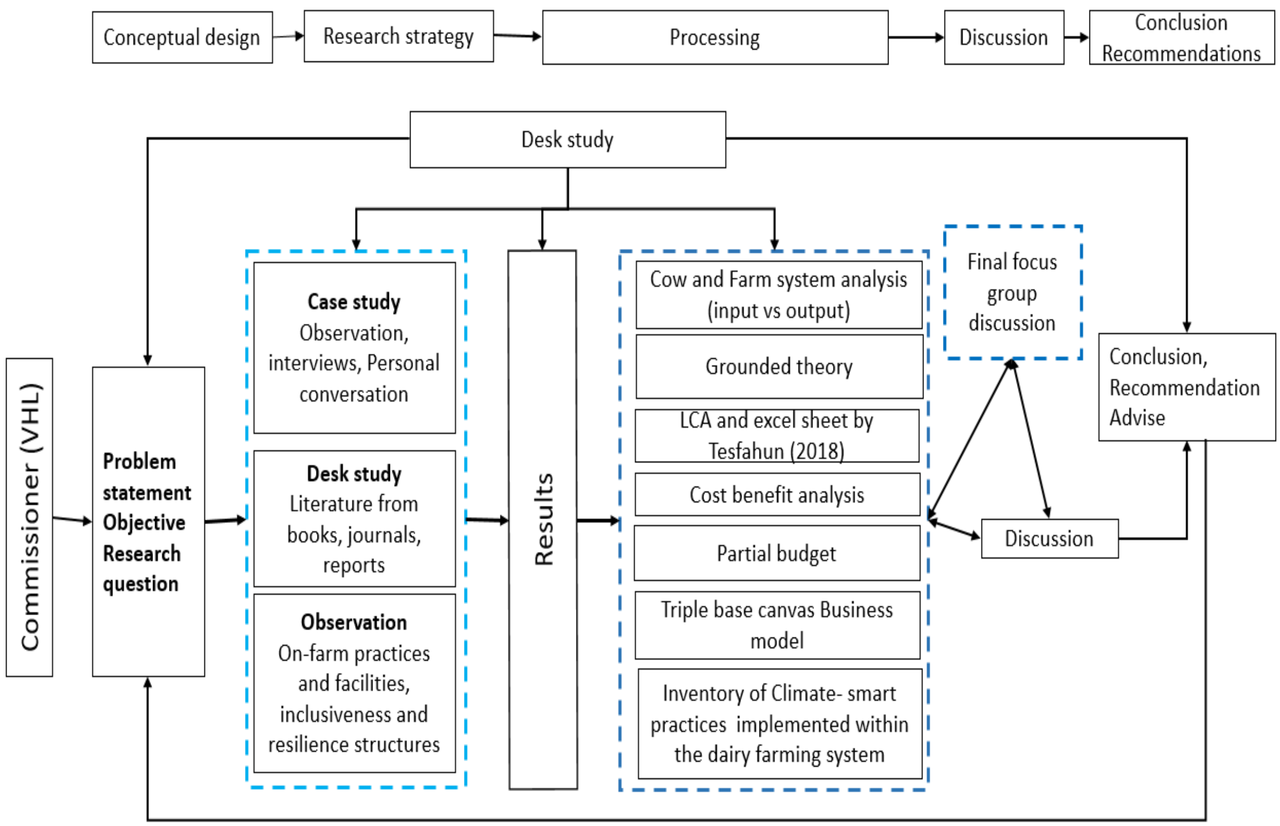
3.5 Limitation of the study

The researcher failed to secure a visa that covers the research time that was planned for fieldwork such that all data was collected in four weeks, as a result, less time was spent per farm than was initially planned. Being a foreigner may have had both positive and negative impact on findings than if an Ethiopian had carried out the research. As a foreigner carrying out research came with a certain level of bias as a result of language barriers and use a translator causing loss of information during translation. The focus group discussion was facilitated by the translator on the researcher's behalf and this may have compromised the validity and reliability of feedback from the focus group discussion. Lack of records by the farmers made very difficult to verify the information so the researcher had to take the farmer’s word and verify through observations. Farmers did not weigh the animals or the feed given to the animal as a result the researcher depended on the total feed ration mixed per day then divide it by the number of animals fed according to livestock units. Allocation of feed was then done using the same bucket and this may have caused errors in the actual feed given per animal. The total feed given to milking cows was not verified if it matched the milk yield and this might have reduced the reliability of findings. Specialised fodder farm could not be located and this led to one of the research units being replaced by a dairy farm with fodder production. Feed producers were not interviewed because there was no direct link with the farmers. Based on personal conversations with the traders at the market, feeds were sold at a spot market by traders who did not know the actual fertiliser application rate nor the total yield per hectare. Therefore, information from key informants such as the crop expert was used to come up with fertiliser application rates and type of machinery and hours worked per hectare and this resulted in a generalisation of the information.

3.6 The research framework

The following research framework was used during the research process and report writing.

Figure 8: The research framework



CHAPTER 4 RESULTS

This chapter presents the findings and data analysis of the field research based on the different tools given in the methodology. All pictures were taken by the author.

Herd size

The herd size was kept constant on the basis that cattle live longer than a year, long calving interval and high calf mortality.

Table 3: Herd structure

	Milking Cow	Pregnant	Dry cow	Ox	Bull	Heifer	Calf	Herd size
WA1	2	0	0	0	0	1	1	4
WA2	14	6	1	0	0	3	5	29
WA3	5	3	2	0	0	1	1	12
ES1	7	1	0	0	3	5	3	19
ES2	20	8	2	4	2	20	8	64
ES3	10	5	2	0	3	10	4	34
ES4	6	2	0	0	3	3	2	16

4.1 Description of the dairy farms

Farm description is based on results from fieldwork and the information was obtained from farmers, observation and farm records when available. Table 4 below gives an account on the farm description and organisational structure.

Table 4: Farm description and structure

	West Arsi 1	West Arsi 2	West Arsi 3	East Showa 1	East Showa 2	East Showa 3	East Showa 4
Location	Melka Oda	Shashamane	Arsi Negele	Ziway	Ziway	Ziway	Adami Tulu
Land size	600m^{2}urban +1.5 ha peri-urban	3ha in peri-urban	450m^2 urban	300m^2 urban	3ha urban	2000m^{2}urban	480m^2 urban
Breed	Holstein-Frisian	Holstein-Frisian + one Arsi cow	Holstein-Frisian	Holstein-Frisian	Holstein-Frisian + Arsi oxen	Holstein-Frisian	Holstein-Frisian
Herd structure	2 cows, 1 heifer, and 1 calf	21 mature milking cows,3 heifers, and 5calves	10 mature cows 1 heifer and 1 calf	8mature cows 3 bulls, 5 heifers and 3 calves	30 mature cows 2bulls, 20heifers 8 calves, and 4 Arsi oxen	17 mature cows, 3bulls 10 heifers, and 4 calves	8 mature cows, 3 bulls, 3 heifers and 2 calves
Feeding system	Zero grazing units	Zero grazing units	Zero grazing units	Zero grazing units	Zero grazing units	Zero grazing units	Zero grazing units
Farming system	Integrated crop-dairy system	Agroforestry, fodder and dairy system	Dairy farming system	Dairy farming system	Dairy farming system + fodder production	Dairy farming system	Dairy farming system
Main product	Milk	Milk	Milk	Milk	Milk	Milk	Milk
On farm milk processing	None	None	None	None	None	None	None
Other revenue streams	Retail business+ wheat production	Coffee, chat, fish, False banana	Retail business	Bull fattening + Restaurant	Bull fattening + retail business	Bull fattening + milk collection and processing	Bull fattening
Ration composition	Concentrate 4116kg crop residues 7665kg	Concentrate, 50863kg crop residue and Napier grass 118260kg	Concentrates 23579kg + crop residues 40515kg	Concentrate 36135kg + residues 59860kg	Concentrate, 102200kg crop residue, maize and Napier grass 308425kg	Concentrates 65335kg + crop residues 142352kg	Concentrates 29565kg + crop residues 50370kg
Labour	1 young man hired	3 young men and 1 old hired	1 young man hired	1 young man and 1 old man hired	10 young man all hired labour	5 young man all hired labour	2 young man all hired labour
Farm management	Farm owner also farm manager	Farm owner also farm manager	Farm owner also farm manager	Farm owner also farm manager	Farm owner also farm manager	Farm owner also farm manager	Farm owner also farm manager

Family labour	No use of family labour	No use of family labour	Use of family labour	No use of family labour	No use of family labour	No use of family labour	No use of family labour
Fodder production	Crop residues from own peri-urban wheat production	Napier grass on site	No fodder production	No fodder production	Napier and maize on site	No fodder production	No fodder production
Record keeping	Poor	Poor	Poor	Poor	Good	Poor	Poor
Main roughage	Wheat straw	Wheat straw and Napier	Wheat straw	Wheat and teff straw	Wheat teff, maize stover, green corn stem Napier grass	Wheat, teff, green corn stem Napier grass	Maize stover, green corn stem, native grass hay
Concentrates	Brewer grain, fagullo frushka	Brewer grain, fagullo frushka, Alema Koudijis dairy ration molasses	Frushka, fagullo, molasses, Alema Koudijis dairy ration	Cottonseed meal ,fagullo frushka	Cottonseed meal, fagullo frushka, Alema Koudijs dairy ration, nug cake	fagullo frushka, nug cake	lentil bran frushka, molasses
Market channels	Restaurant and farm gate	Restaurant, retailing point And farmgate	Restaurant, retailing point and farmgate	Restaurant, milk processor and farmgate	Restaurant, Hotel, milk processor and farmgate	Farmgate, processing and retailing	Farmgate
Breeding system	AI	AI	AI	AI + bull as back-up	AI	AI + bull as back-up	AI
Value chain function	Producer and retailer	Producer and retailer	Producer and retailer	Producer and retailer	Producer and retailer	Producer, collector, processor and retailer	Producer and retailer
Sex of farmer and age	Male, 50	Male,29	Male, 47	Male, 40	Male,31	Male,39	Female,38
Education level	Grade 8	Grade 12	Grade 8	Diploma	Grade 8	Grade 12	Grade 10
Future business plan	Continue as a producer	Continue as a producer	Continue as a producer	Plan to open a milk collection and processing unit	Plans to open a milk processing plan already in progress	Continue producing milk, collecting, processing and retailing	Continue as a dairy farmer retailing all milk at farmgate

4.1.2 Farm production performance

The productivity per cow was measured based on indicators given in table 5. Calving interval was compared with the number of cows that give birth per year and the number of calves in the herd to make sure they are comparable. Milk production per lactation, age at first calving, number of cows that calve every year and replacement rates are based on the information given by the farmers and the rest are findings calculated based on equations 7.

Table 5: Production performance per farm

Farm	Milk production per lactation (litres)	Lactation days	Age at first calving (months)	Calving interval (months)	Lactation length per year (days)	Litres milk per year	Average production per day (litres)	Peak lactation (litres)	Replace ment rate (years)
WA1	2160	270	24	450	219	1752	4.80	8.16	4
WA2	3510	270	36	540	183	2373	6.50	11.05	7
WA3	3073	270	24	480	205	2337	6.40	10.88	7
ES1	2376	270	30	540	183	1606	4.40	7.48	7
ES2	5225	270	26	450	219	4238	11.61	19.74	6
ES3	3675	250	30	480	190	2795	7.66	13.02	7
ES4	2891	300	24	540	203	1954	5.35	9.10	8
Ave	3273	271	28	497	200	2436	7	11	7

In a study by Kebede, (2015) on Holstein Frisian breed in Ethiopia, lactation length of 252 days, milk yield per lactation of 2149 litres, peak lactation of 11.39 litres, age at first calving of 36 months and calving interval of 462 days were found and they are much lower than observed in this study. The main constraints were feed shortages, high feed cost, scarcity of veterinary delivery and inefficient service and these also observed in this study.

4.1.4 Cost price

The costs captured in this study are based on the information given by the farmer. Capital assets in the fixed cost included depreciated costs, the life span of the asset, interest, and maintenance was taken into account. Maintenance of buildings was captured at 2% of the investment value. Interest rate 11% from the commercial bank. Maintenance cost is 2% of the total cost of investment whilst for the choppers and milking machine 10% of the cost of investment. The interest rate was captured at 10%. Running cost was captured in the variable section as the cost of electricity. All prices are in Ethiopian Birr (ETB). Current exchange rate 0.031:1 Euro. The formulas to calculate depreciation, interest, and maintenance cost are given below. Family labour cost in this study is based on the opportunity cost of the farmer employing a farm manager. The value of manure is based on the cost of buying fertiliser if the farmers were to use artificial fertiliser instead of manure according to information from key informant 1. The milk price fluctuates with fasting seasons also observed by Zijlstra et al., (2015) and Brandsma et al., (2013) therefore an average of the fasting and none fasting season market price was used. Equation 26 was used to calculate value for product such as manure that does not have a direct market price. The fixed cost, variable cost, and gross margin were calculated using equations 1-5.

$$\frac{\text{new value - scrap value}}{\text{useful life in years}} = \text{annual depreciation costs}$$

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

Table 6,7 and 8 below shows how the cost of capital goods such as buildings, choppers, and the milking machine was calculated.

Cost of buildings

Table 6: Cost of building cost [Etb]

Farm	Cost of investment	Life span	Depreciated cost	Maintenance 2%	Interest 11%	Cost of buildings
WA1	17000	8	2125	34	935	3094
WA2	400000	8	50000	800	22000	72800
WA3	128000	8	16000	256	7040	23296
ES1	350000	10	35000	700	19250	54950
ES2	2000000	20	100000	4000	110000	214000
ES3	200000	20	10000	400	11000	21400
ES4	200000	10	20000	400	11000	31400

The farms in West Arsi were made of poles and mud, therefore, a shorter life span was used than buildings made of bricks and steel.

Cost of choppers

Table 7: Cost of choppers[Etb]

Farm	Cost of investment	Life span	Depreciated cost	Maintenance 10%	Interest 11%	Value of choppers
ES1	12000	5	2400	1200	660	4260
ES2	24000	5	4800	2400	1320	8520
ES3	14400	5	2880	1440	792	5112

Cost of milking machine

Only one farm had milking machines

Table 8: Cost of milking machines[Etb]

Farm	Cost of investment	Life span	Depreciated cost	Maintenance 10%	Interest 11%	Value of choppers
ES2	120000	5	24000	12000	6600	42600

The total cost varied greatly between farms mainly as a result of the size of the farm and choice of feeds and level of investment on the farm. In table 9. WA1 is the smallest farm but has the highest cost of production whilst WA3 has the lowest.

Table 9: Total costs and production cost [ETB]

Farmer	Total herd	Fixed costs	Variable costs	Total cost	Production cost / litre
WA1	4	73782	39436	113218	26.31
WA2	29	253267	756550	1009817	19.49
WA3	12	108676	248325	357001	16.13
ES1	19	167010	374680	541690	24.57
ES2	64	664544	1428700	2093244	20.03
ES3	38	160212	717625	877837	20.32
ES4	16	108800	490200	599000	25.90

Total revenue and gross margin

Annual milk produced per cow, the revenue, and total variable cost are based on the information given by the farmer. No growth in herd size was considered in this study based on the fact that the study only captures one year and cattle are kept longer than that and also the long calving interval and calf mortality of 2%. Gross margins were calculated based on equations 1-5.

Table 10: Total revenue and gross margin[ETB]

Farmer	Total herd	Milk revenue	Revenue from animal sales	Revenue from manure	Total revenue	Gross Margin/litre of milk
WA1	4	84096	0	5400	89496	14.29
WA2	29	1046273	9000	6900	1062173	6.13
WA3	12	392576	39000	0	431576	9.80
ES1	19	282656	136000	0	418656	3.42
ES2	64	2424168	480000	16200	2920368	13.54
ES3	38	1045155	35000	0	1080155	7.63
ES4	16	406453	37000	0	443453	-2.99

Production cost and profitability [ETB]

The price of milk varied with the area and market channel. The profit per litre of milk is very low when milk only is considered and it goes up when other dairy products are considered. And this shows the importance of capturing the economic value of products and how it can increase the total profit per litre of milk.

Table 11: Production cost and profitability

Farmer	Production cost per litre	Price of milk	Price of milk with other products	Profit /litre for all products	Profit from milk only
WA1	32.31	24	25.25	-7.06	-8.31
WA2	20.27	21	21.31	1.04	0.73
WA3	19.10	21	22.76	3.67	1.90
ES1	42.16	22	28.17	-13.99	-20.16
ES2	19.00	22	26.75	7.75	3.00
ES3	18.48	22	22.81	4.33	3.52
ES4	38.32	26	27.60	-10.72	-12.32

In this study the profit margin based on revenue from all the products was used

Annual farm budgets

For farmers without crop production and there was no market for manure, it becomes an expense as farmers have to pay a transportation fee to dispose of the manure at municipality designated areas. No polluter pays fees were observed hence some of the manure is dumped within residential areas and very close to the lake. As shown in table 12, WA1 has the lowest gross margin and annually it's making a loss this was confirmed by the fact that the farmer had to cut his herd size two years ago.

Table 12: Annual farm budgets [Etb]

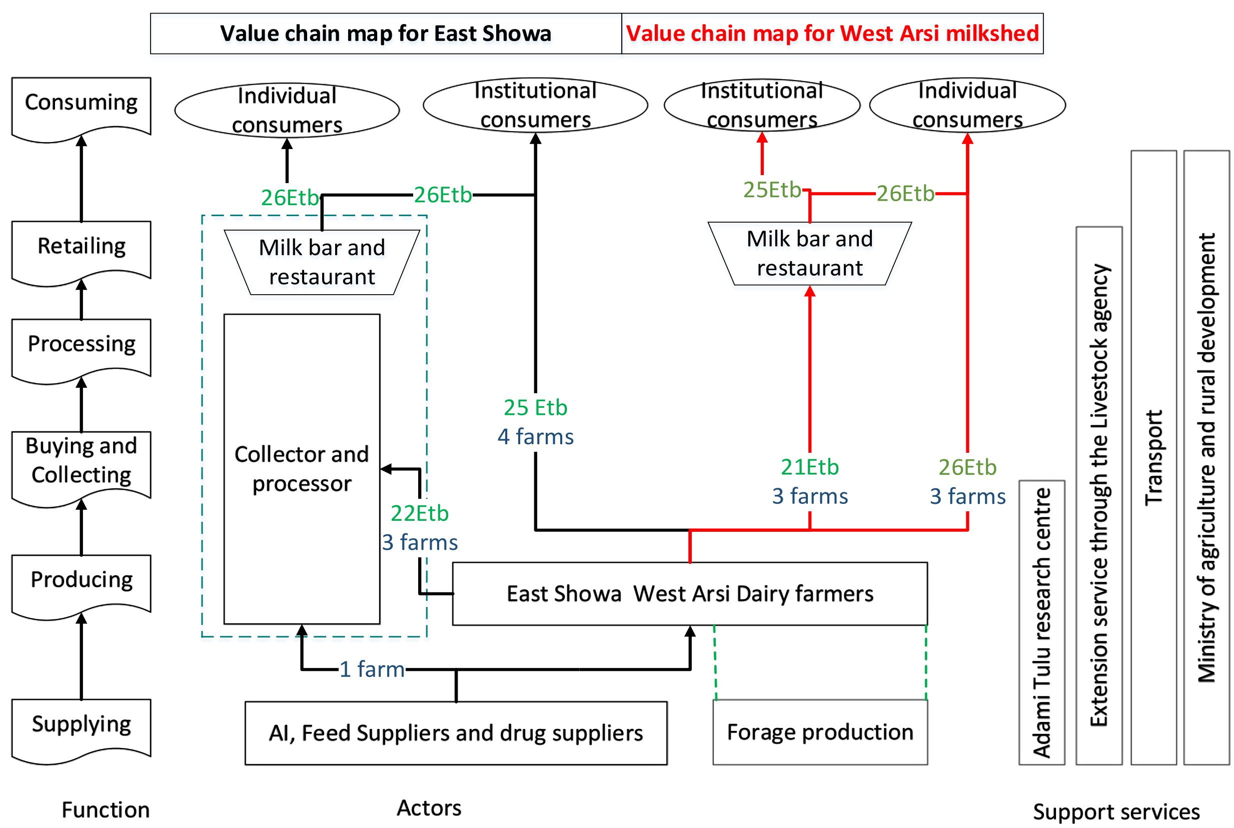
	WA1	WA2	WA3	ES1	ES2	ES3	ES4
Variable cost							
Feed cost	24000	720000	240000	360000	1333200	700000	475200
Verterinary care	1000	12000	500	1680	18000	6000	600
Cow maintanance	1200	6000	6000	6000	18000	5000	0
AI	156	2050	625	1000	2500	625	4800
Transport	480	9600	1200	6000	36000	6000	9600
Ploughing	7200	0	0	0	4800	0	0
manure cost	5400	6900		0	16200		0
Toatal Variable cost	**39436**	**756550**	**248325**	**374680**	**1428700**	**717625**	**490200**
Fixed cost							
Permanent labour	14400	57600	12000	28800	144000	72000	24000
Family labour cost	50688	96000	72000	48000	96000	36000	36000
Farm maintenance	5000	24000		24000	68000	24000	0
Electricity and water bills	600	0	1200	1200	16824	1200	6000
Rent	0	2667	180	800	3000	500	3000
Land tax	0	200	0	0	51600		8400
Animal housing	3094	72800	23296	54950	214000	21400	31400
Milking cane	0	0	0	5000	20000	0	0
Choppers	0	0	0	4260	8520	5112	0
Milking machine	0	0	0	0	42600	0	0
Total fixed cost	**73782**	**253267**	**108676**	**167010**	**664544**	**160212**	**108800**
Total cost	**113218**	**1009817**	**357001**	**541690**	**2093244**	**877837**	**599000**

Revenue							
Milk revenue	84096	1046273	392576	282656	2424168	1045155	406453
Bull calves sales	0	9000	9000	6000	0	0	0
Old cow sales	0	0	30000	130000	480000	35000	37000
Manure	5400	6900		0	16200		0
Total revenue	**89496**	**1062173**	**431576**	**418656**	**2920368**	**1080155**	**443453**
Gross margin	**50060**	**305623**	**183251**	**43976**	**1491668**	**362530**	**-46747**
Annual profit/loss	**-23722**	**52356**	**74575**	**-123034**	**827124**	**202318**	**-155547**

4.1.5 Revenue stream

Though milk was the main source of income, old cows, bull calves were pen fattened and sold to the slaughterhouses. Only farmers in East Showa kept bulls with two farmers as back-up since the AI system was not reliable, also observed by Zijlstra et al., (2016). Other than the dairy farming business the farmers had other businesses such as crop production, restaurant, milk collection, processing, and retailing and grocery shop. Milk revenue was affected by fasting seasons, location and market channel used as shown in figure 9. Milk price fluctuation as a result of fasting was also observed by Zijlstra et al., (2015) and Van Geel et al., (2018).

Figure 9: Dairy value chain map



4.1.2 Volume of feed and seasonal variation

The farmers invested in feed storage areas (sheltered or open) and they buy all their roughage requirement during the harvesting season so that they do not have to buy when there is a short supply. Farmers reported feed shortage during the months of February to March and July- August and during this time feed cost go up by about 20%. As a result of the farmers stockpiling, supplementary concentrates and fodder production in farms that have fodder production, the farmers were not affected by the price hikes during the feed scarcity season nor did they report having a shortage of feeds. In order to improve dairy farm profitability and reduction in methane emissions, the researcher agrees with Løvendal et al., (2018) and Waghorn and Hegarty, (2011) that managing feed supply and quality is the starting point.

Figure 10: On-farm feed storage

Only 29% (2 out of 7) of the farmers had fodder production as a subsystem within the dairy farm however, they grew Napier grass and maize only. Leguminous plants and trees were not observed although, one of the farmers plans on including leguminous plants in his fodder production. The farmers with fodder production did not produce enough fodder to cover the annual requirement, therefore, they outsourced additional roughage just like farmers without fodder production system this was due to inadequate land. The research initially aimed at including specialised fodder production, however, no specialised commercial fodder production could be found and a replacement was made with a dairy farmer with fodder production. As a result, feed supply remains a weak link in dairy farming and this was also confirmed by Zijlstra et al., (2015) and Brandsma et al., (2013).

Concentrate usage was observed in all farms although the choice of concentrates varied with farmer preference, availability and the cost of the concentrate. Use of brewer grain was only observed in West Arsi. Farmers keep smaller amounts of concentrate on the farm in comparison to roughages despite the fact that just like the roughages the price also fluctuates. The main reason cited for not stocking larger amounts of concentrate is because they are expensive. Table 13 shows concentrate consumption per farm calculated based on daily consumption of each feed per day as given by the farmer at the time of data collection therefore seasonal variation in concentrate usage may have been missed.

Table 13: Concentrate usage per farm per year [Kg DM]

	Brewery grain	Frushka(Wheat bran)	Fagullo (linseed meal)	Lentil bran	Cotton seed meal	Nug cake	Mola sses	AK dairy ration	Concentr ate
WA1	1050	1533	1533	0		0	0	0	4116
WA2	13633	12775	12775			0	2555	11680	53418
WA3		8103	8103				1898	5475	23579
ES1		12045	12045		12045				36135
ES2		40150	10075		10000	20075		21900	102200
ES3		43800	12045			9490			65335
ES4		21170		6570			1825		29565

Farmers chose to use various crop residues and wheat straw was common in all the farms. The use of fresh grass, green corn stem was observed although at times they were used as alternatives depending on availability. Table 14 shows annual roughage consumption calculated based on daily consumption of each feed per day as given by the farmer.

Table 14: Roughages feeds consumption per farm per year [Kg DM]

	Wheat straw	Maize stover	Teff straw	Fresh green grass	Green corn stem	Native grass hay	Napier grass	Total
WA1	7665							7665
WA2	45260						18250	63510
WA3	40515							40515
ES1	29930		29930					59860
ES2	63875	63875	63875		14600		14600	220825
ES3	43800		43800	7300	6388			101288
ES4		18250			4015	16060		38325

The prices of feed varied from one farmer to the other and also from one feed agent to the other, therefore, the average of the buying price by the farmer and the selling price by the feed agents was used to come up with the market price for feed as shown in table 15. Only the dairy ration from Alema Koudijs was clearly labelled therefore it was difficult to tell if the price differences were a result of different grades for the same feed. Lack of record and receipts made it difficult to verify the prices given by farmers. The price of fodder used in this study is the opportunity cost of buying the fodder.

Table 15: Prices of feeds per region[Etb]

Region	Fodder	Price /kg	Crop residues	Price /kg	Non forage resources	Price /kg
West Arsi	Napier grass	5	Wheat straw	1	Brewery grain	2.8
			Barley straw	1	Alema Koudijs dairy ration	15
					Frushka	7
					Fagulo	12
					Salt	7.1
					Molasses	4.4
East Showa	Napier grass	5	Maize Stover	2	Fagullo	20
	Maize	5	Wheat straw	1	Frushka	6.5
			Teff straw	1	Alema Koudijs dairy ration	15
					Cottonseed meal	7
			Green corn stem	5	Molasses	4.4
			Grass hay	2	Lentil bran	7
			green grass	5	Nug cake	20
					Effective micro-organism 2	30
					Salt	7.1

Figure 11: Napier grass and maize production in Ziway and Shashamane

4.2 Climate smart practices

Climate smart practices implemented were grouped under the theme of feeds, water, animal welfare, energy consumption, manure management and maximizing productivity are summarised in table 11.

Table 16: Climate smart practices identified and the level of adoption

The level of adoption is colour coded with red<30%, yellow ≥30-60%, and green≥60%. No colour represents a climate smart practice that was not implemented.

Theme	Indicators	WA1	WA2	WA3	ES1	ES2	ES3	ES4
Feeds	Fodder production		Green			Green		
	Use of concentrates	Green	Green	Green	Green	Green	Green	Green
	Straw treatment					Red	Red	
	Use on mineral supplements	Red	Red	Red	Red	Yellow	Red	Red
	Accuracy in feed allocation	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Electricity consumption	Minimum use of machinery	Green	Green	Green	Yellow	Yellow	Yellow	Green
	Use of milking machine					Green		
Water	Water availability	Red	Red	Red	Green	Green	Green	Green
	Water quality	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Yellow
	Water harvesting from wells				Yellow	Yellow	Yellow	Yellow
Animal welfare	Improved housing	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	Herd health management	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	Cow maintenance (hoof trimming and dehorning)	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	Use of antibiotics	Red	Red	Red	Red	Red	Red	Red
	Zero-grazing units	Green	Green	Green	Green	Green	Green	Green
	Cowshed with concrete floors for easy cleaning	Green	Green	Green	Green	Green	Green	Green
Manure management	Biogas		Yellow	Yellow	Yellow		Yellow	
	Separation of urine and cow dung	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	Use of manure as a fertiliser	Yellow	Yellow			Yellow		
Maximising productivity	Use of improved breeds	Green	Green	Green	Green	Green	Green	Green
	Use of artificial insemination	Green	Green	Green	Yellow	Yellow	Green	Green
	Replacing male animals with females	Green	Green	Green	Yellow	Yellow	Yellow	Yellow
	Cow productivity (age at first calving and calving interval)	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	Ration formulation and feed conversion efficiency	Red	Red	Red	Red	Red	Red	Red

Where drinking water from the municipality was available the quality is assumed to be of potable, water from the stream was dirty and murky. Water harvesting was observed in East Showa farms with water pumped from wells and stored in reserve tanks. The quality of the water was questionable considering the well is in close proximity to the solid storage that does not have a lining or the overflowing septic tank. Although not proven, it may mean the water is to some extent contaminated by dung and urine though the farmers mentioned that the water was for cleaning only. Straw treatment procedure is done by mixing a litre of EM2 is diluted by 16 litres of water and a litre of molasses is added them mixed with the straw and then incubated for 30-40 days before feeding

4.3 GHG emissions

4.3.1 Off-farm (upstream) GHG emissions

All farmers in this research outsource all or part of their feed. A direct connection with the actual feed farmers could not be made. Conversations with the traders were carried out to find out if some of the traders at the market to find out if some of them were also crop farmers. Information from key informant 1 who is a crop expert from Adami Tulu research centre was used to come up with fertiliser application rates and machinery usage.

Fertilizer production and application rates

Fertiliser application rates in table 17 are the same for both regions although there is a difference in yields with West Arsi having a higher yield than East Showa with the exception of teff. This is attributed to the difference in production systems and agro-ecological zone. The figures in table 17 were used in calculating off-farm feed production.

Table 17: Fertiliser application rates and yield per hectare

	Fertilizer application /ha		West Arsi yield per crop/ha		East Showa yield per crop/ ha	
	DAP	Urea	Grain	Straw	Grain	Straw
Wheat	100	150	3420	11935	2940	10261
Barley	100		2980	12516	2055	8631
Teff	130	80	1560	7488	1750	8400
Maize	100	150	4000	10400	3500	9100
Napier grass			3150	9450	3150	9450

Source: Key informant 1

GHG emissions from fertiliser application and use of machinery during feed production

Farmers in this study do not have enough land to produce all their feeding requirements, information from key informant 1 was used to come up with fertiliser and machinery emissions. In this study, the GHG emissions during feed production were calculated for both the on-farm and off-farm productions. Based on the annual roughage (table 9) given by the farmer and the yield per hectare (Table 12) an estimate of total land that is cultivated to produce the farm annual roughage consumption. The total land from this calculation was then used to generate the fertiliser consumption and hours worked by tractors and combine harvesters during ploughing and harvesting as shown in table 19. The emission factor of 2.67 kg CO_2 /litre for the consumption of diesel fuel was used in calculating emissions from tractors and combine harvester (Gabre, 2016). According to the key informant 1, in West Arsi and East Showa, the use of machinery during ploughing and harvesting is 50% and 20% respectively. Limited use of machinery was observed at WA2 because the farmer has an agroforestry system growing coffee, chat, false banana, and Napier grass. The GHG emissions resulting from fertiliser application in table 13 were calculated using equation 10-16.

Table 18: Fertiliser and machinery emissions from all crop residue production [KG of CO_2/Litre FPCM]

Farm	Total land	Total litre consumed /year	Emission from machine	Emission from fertilizer application equivalent CO_2	Emission from fertilizer and farm machinery	Allocation proportion to crop residue	Emission allocated for crop residue	Emission allocated for crop residue
WA1	1.5	98	260	842	1103	0.51	564	0.16
WA2	5	0	0	2808	2808	0.48	1350	0.03
WA3	2.5	144	384	1404	1788	0.51	914	0.05
ES1	3	195	521	1685	2205	0.51	1128	0.09
ES2	8	1120	2990	4492	7483	0.51	3826	0.03
ES3	4	320	854	2246	3101	0.51	1585	0.03
ES4	2.5	144	384	1404	1788	0.51	914	0.06

Weiler et al. (2014) estimated that off-farm concentrate production and processing produced a total emission of 1.36 Kg CO_2/Kg and this was used in estimating current GHG emissions. Although feeding concentrates is necessary for improving nutritive content and digestibility in the feed ration, there are GHG emissions produced as a result of feeding concentrates through processing and transportation. As shown in table 19 GHG emissions were calculated by multiplying total concentrates fed by the emission factor of 1.36 Kg CO_2-eq per kilogram of concentrate (Weiler et al., 2014).

Table 19: Emission from concentrate production and processing [Kg CO_2 eq]

Farm	Total concentrate usage	Emission per kg	Annual emisson per farm	Enteric emission per liter/yr
WA1	4116	1.36	5598	1.60
WA2	53418	1.36	72648	1.46
WA3	23579	1.36	32067	1.72
ES1	36135	1.36	49144	3.83
ES2	102200	1.36	138992	1.26
ES3	65335	1.36	88856	1.87
ES4	29565	1.36	40208	2.57

East Showa farms have high concentrate emissions including even in farms such as ES2 that has high milk yield and this can be attributed to the herd structure that includes males. The variation in milk yield and emissions indicate that other factors may be affecting the productivity of the cows.

Feed transportation

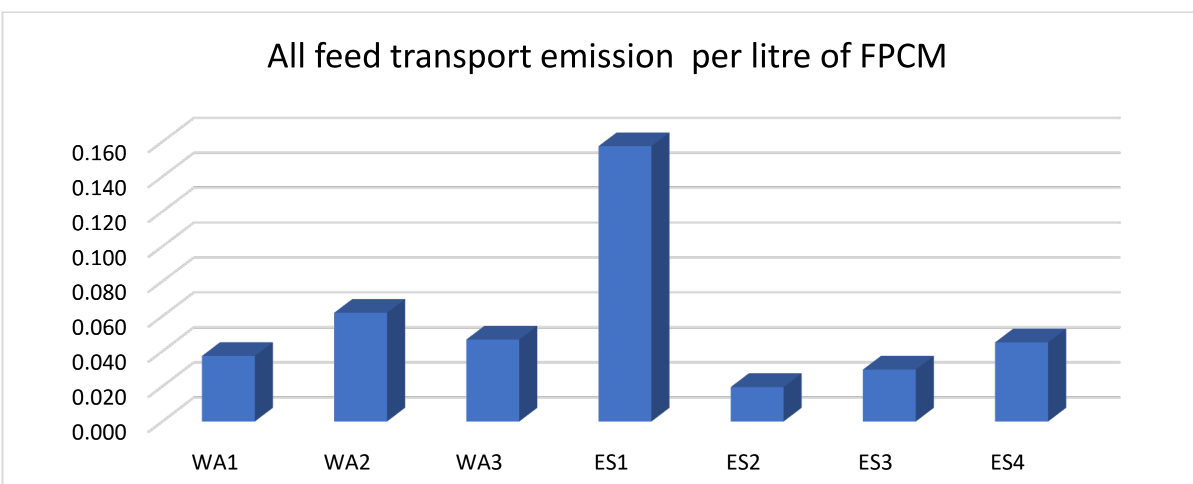
Based on the information given by key informant 2 (feed agents) concentrates are sourced from Adama, Hawassa, Debre Zeit, Matehara and Wonji-Shewa and are transported using the diesel Isuzu 3,5 tonne trucks to various feed distribution points (feed retailers). Farmers buy and transport the feeds from the feed agents using donkey carts. Therefore, the emissions calculated are based on the emissions by the

Isuzu truck and the distance travelled from the feed processing plant to the main feed distribution point for each town per year.

Figure 12: Mode of transport in the transportation of feeds

Transport emissions vary with the size of the farm, distance from the processing plant and the total feeds fed. Concentrates contribute the most in transport emissions due to the use of a diesel-powered Isuzu truck whilst most forages are transported using donkey carts. The emissions from fuel consumption during feed transportation or land preparation and harvesting were calculated using Equation 16 and an emission factor of emission factor 2.67 kg CO_2 /litre for the consumption of diesel fuel (Gabre, 2016). As shown in figure 13 WA2 is located in the peri-urban and has the longest distance and this has resulted in high transport emissions.

Figure 13: Total emissions during transportation of feeds [KG CO_2/litre FPCM]



4.3.2 On-farm emissions

Gross energy intakes per animal in a cohort per day

Gross energy intakes per animal in a category was calculated based on the dairy ration fed as given by the farmhand and researchers observation as shown in table 20. Feed ration consisted of crop residues supplemented with concentrates. Allocation of feed was done using a standard bucket and the farmhand estimates the amount given to each cow based on livestock unit. This may have caused underfeeding in high yielding cows. Gross energy intakes per animal were calculated using equation 17.

Table 20: Gross energy intakes per animal in a cohort/ day [unit: MJ/day]

Farm	Milking cow	Pregnant	Dry cow	Ox	Bull	Heifer	Calves
WA1	285	0	0	0	0	244	94
WA2	312	269	269	0	0	215	81
WA3	307	244	242	0	0	194	81
ES1	304	304	0	0	364	243	91
ES2	383	232	255	183	306	164	77
ES3	244	244	244	0	270	170	73
ES4	287	287	0	0	330	226	91

Enteric emission compared to total FPCM based on Tier 2

Milk yield was based on information from the farmer. Record keeping is very poor (except for one farmer) and this made it difficult to verify the information. The FPCM was calculated using equation 6 and enteric emissions were calculated using equation 18 and 19. Actual fat and protein percentages could not be obtained therefore the standard 4.0% fat and 3.3% protein was used.

Table 21: Annual FPCM and enteric emissions

Farm	Milk yield per year	Total emission of all animals (Kg CH_4/yr)	Total emission Kg CO_2-eq/yr	FPCM @4.0% fat and 3.3% protein	Emission per liter (FPCM) (Kg CO_2)
WA1	3504	387	8133	3500	2.32
WA2	49823	2917	61253	49773	1.23
WA3	18694	1290	27085	18675	1.45
ES1	12848	2135	44840	12835	3.49
ES2	110189	6502	136534	110079	1.24
ES3	47507	2965	62262	47460	1.31
ES4	15633	1766	37089	15617	2.37

As shown in table 21 there is an inverse relationship with farms with high milk productivity per cow having low enteric per litre of milk and this was also observed by Tesfahun (2018) and Van Geel et al. (2018) in studies carried out in Oromia. According to Gerber et al. (2011) GHG emission intensity is found to be inversely related to productivity, reflecting the strong effect of increased efficiency and dilution of emissions across a larger volume of milk and this concurs with the findings. The increase in high milk yield is attributed to high yielding exotic crossbreeds, herd health management, and improved feed rations. Based on Tesfahun (2018) GHG emission of 2.01kg eq CO_2/litre for dairy farmers in the urban area with exotic crossbreeds whilst the peri-urban farmers had 5.92 kg eq. CO_2/litre mainly coming from low yielding indigenous breeds were observed. This confirms that ES2 ,3 and WA2 in this study were above the average dairy farm in this region including the peri-urban farm. The difference in emission between ES1 and ES2 could be attributed to better nutrition as ES2 adds supplementary minerals, Alema Koudijs dairy ration adlib access to water, Napier grass whilst ES1 doesn't, and this could be the reason for the difference in FPCM GHG emissions. Although both farms have male animals ES1 is a smaller farm and the three bull contributes more to the emissions than the same number in a bigger farm.

Volatile Solids excretion(VSE) and Manure management system and GHG emissions

The volatile solid rate varies with farms and this is attributed to the overall digestibility of the ration, size of the animal and daily feed intake. The lower the digestibility the higher the VSE resulting in more manure being generated also observed by Kitaw et al. (2018). VSE was calculated using equation number 21. The VSE was calculated based on gross energy intake and this considers the different age groups. The main manure management systems in the farms were solid storage and anaerobic digester as summarised in table 22 and figure 14. All farmers mentioned that they use composting system however, the system did not conform to the characteristic of compost by IPCC (2006), therefore, a solid storage system was more appropriate since no turning or aerobic treatment was done. The cow barn had a gentle slope on the floor that allowed urine to flow out of the barn and this reduced GHG emissions since cow dung and urine remain separated. The cow dung is regularly removed and disposed into the solid storage or the biogas digester whilst the urine flows into a septic tank together with other liquid effluents from cleaning. The manure pits did not have any lining, therefore, leaching of nutrients and pollution of groundwater reserves take place. To calculate direct and indirect methane emissions the equation 22 was used.

Table 22: CH_4 and N_2O emissions from manure management systems [Kg CO_2/Litre FPCM]

Farm	Manure management system	VS per day per animal (KG)	Total manure	CH_4 emission /litre	Emission N_2O per litre	Emission CH_4 & N_2O per liter
WA1	Solid storage	4.44	6478	0.023	0.15	0.17
WA2	Anaerobic digester & solid storage	4.84	51242	0.023	0.07	0.09
WA3	Anaerobic digester & solid storage	4.94	21632	0.026	0.07	0.10
ES1	Solid storage	5.21	36125	0.035	0.23	0.26
ES2	Solid storage	4.48	104749	0.012	0.08	0.09
ES3	Anaerobic digester & solid storage	3.94	97906	0.023	0.13	0.16
ES4	Solid storage	4.46	26046	0.021	0.13	0.15

ES1 has very high VSE and low milk yield, this resulted in high emissions from manure, showing the linkage between high GHG emissions and reduced milk yield and gross margins. ES1 has a newly constructed biogas digester though it was not yet functioning at the time of fieldwork. Farms with anaerobic bio-digester had lower CH_4 emissions in comparison to farms with the solid storage system. The anaerobic digesters were not big enough to manage the daily manure production as shown in WA2 and 3. High milk output per animal had an effect of reducing the emission per litre of milk as shown by ES2.

Figure 14: Images showing manure management systems

Anaerobic bio-digester | Pit solid storage | Heap solid storage

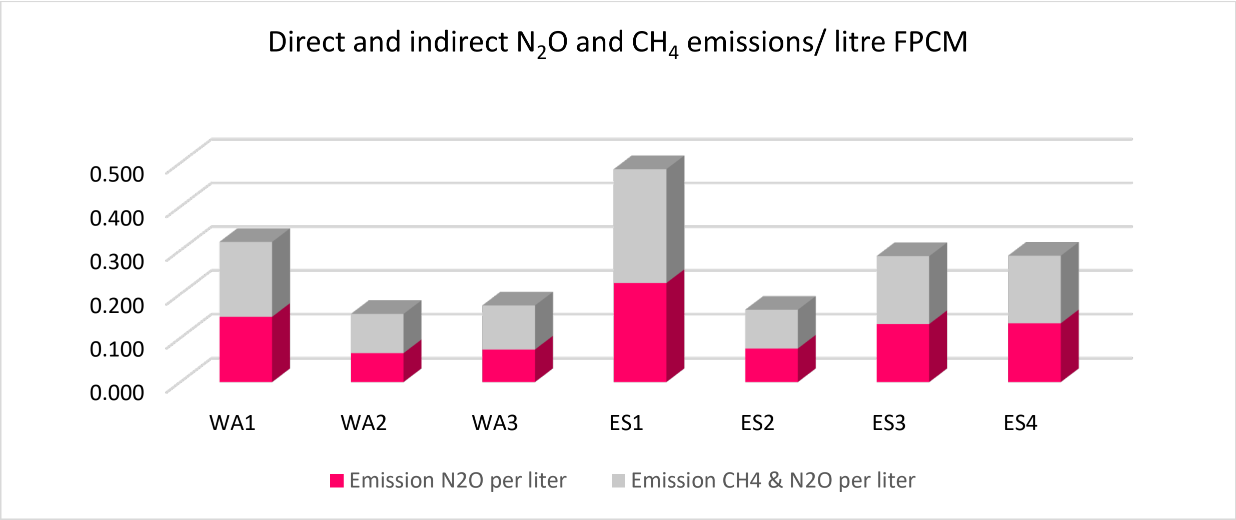
WS2 uses the pit solid storage system but failed to separate the liquid effluent and the dung such that they combined, together with rainwater the solid storage system ended up looking like a slurry manure system and this increase the GHG emissions (IPCC, 2006). The Napier grass acts as a vegetative filter strip filtering the water in the effluent. Both solid storage and anaerobic digester were carried out for 12 months.

Figure 15: Solid storage before and after the rain

Direct and indirect N_2O and CH_4 emissions from manure management

Direct and indirect N_2O emissions during manure management occur as a result of volatilisation, leaching, and runoff. Nitrous emissions during manure management were calculated using the equation 22-26. Both direct and indirect emissions are high though if productivity per cow is high the emissions are spread out as shown by low emissions per litre by ES2 farm, WA2 and 3 as shown in figure 16. The use of an anaerobic biogas digester reduces both direct and indirect N_2O and CH_4.

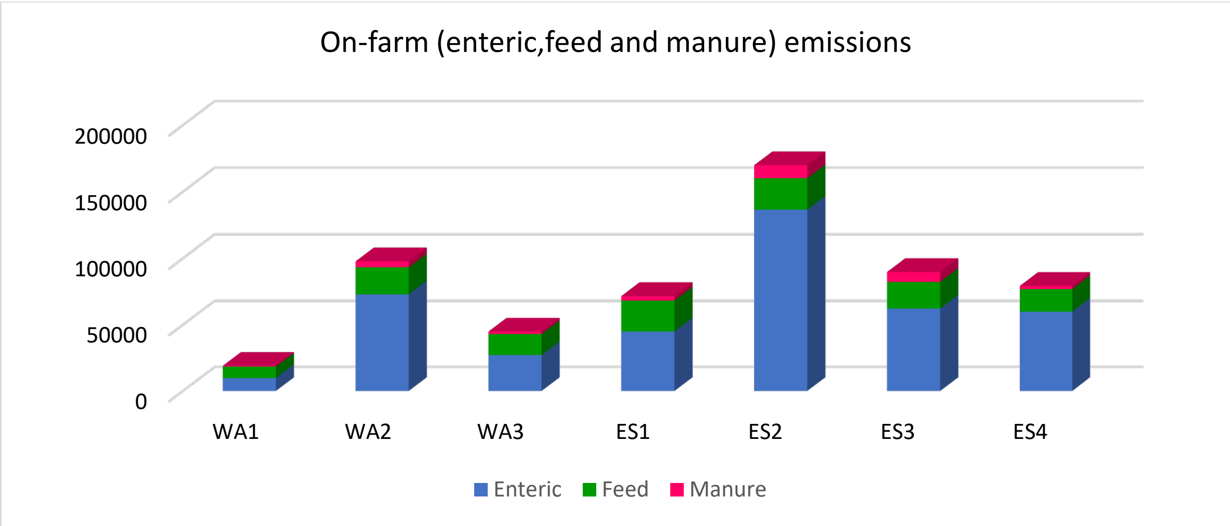
Figure 16: Direct and indirect N_2O and CH_4 emissions [Kg CO_2 eq/ Litre]



Summary of all emissions

In all the farms' enteric fermentation contributed the highest to on-farm GHG emissions, however, the percentages found in this research are much higher than those found by Tesfahun, (2018).

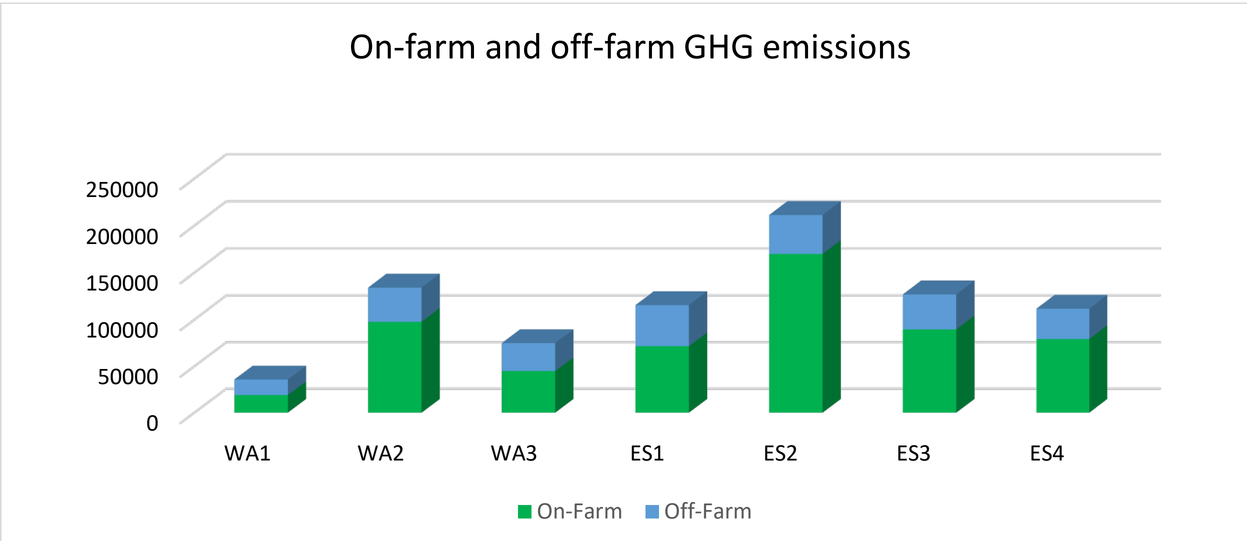
Figure 17: On-farm (enteric, feed and manure) [Kg CO_2 eq/year]



On-farm emissions were much higher than off-farm emissions and this was also observed by Tesfahun (2018). However, in this study, the emissions exceed 80% in all the farms as a result of high dry matter intake per animal and high usage of concentrate. In this study, all concentrates were considered unlike in

Tesfahun (2018) who focused on the dairy ration only. On cow basis emissions went up with the use of concentrates and increased feed intake but emissions decline as animal productivity increases and this was confirmed by Gerber et al. (2011). WA1 has the highest emissions and it has an annual loss of 14Etb per litre whilst ES2,3 and WA2 have the lowest GHG emission and higher profit per litre of milk.

Figure 18: On-farm and off-farm GHG emissions [Kg CO_2 eq/year]



The carbon footprint of milk [Kg CO_2 eq/litre]

Enteric emission ranged between 78-87% in the study area whilst the carbon footprint ranged between 1.68 and 3.69 kg CO_2-eq per litre of FPCM. These emissions are much lower than observed by Tesfahun (2018) who found a carbon footprint of 2.07 and 4.71kg CO_2 eq unallocated emissions in urban and peri-urban farms. The peri-urban farmer (WA2) in this study has exotic breed just like urban farmers and has a carbon footprint of 1.68Kg CO_2 eq/litre much lower than the other urban farmer. This confirms that the farms in this study are in the urban farming system and the case studies were not very representative of the farming system in the milkshed. Although in both studies enteric emissions contributed the most in on-farm and off-farm emissions. The relationship between the carbon footprint and profitability shows a trend of farms with low carbon footprint also having high profit as shown in WA3 and ES2 whilst WA1 show high emissions and a loss.

Table 23:Carbon footprint of milk and economic profit per litre

	WA1	WA2	WA3	ES1	ES2	ES3	ES4
Carbon footprint [Kg CO_2 eq/FPCM litre]	4.42	1.70	2.15	5.07	1.47	1.76	3.29
Profit /litre all products considered [ETB]	-7.06	1.04	3.67	-13.99	7.75	4.33	-10.72

According to FAO (2010), a carbon footprint of 2.4 and 7.5kg CO_2 was estimated as the global average for sub-Saharan Africa and the emissions in this study fall within this range. The current study shows an improvement in GHG reduction although more can still be done considering OECD countries carbon footprint ranges between 0.84 and 1.3kgs CO_2 eq per kg FPCM (De Vries and De Boer, (2010).

Allocation factors

Weiler et al. (2014) allocated emissions based on the multi-functionality of cows included milk for home consumption, milk for sale, cattle sales, dowry and wealth for peri-urban farmers whilst urban farmer allocations were according to milk, meat, draught, finance, and insurance. The peri-urban farmer kept cattle for milk, other functions such as dowry and wealth were not considered by the farmer, therefore, functions as urban farmers were used. All farmers have specialised dairy farming systems, therefore, milk an economic function as it generates income as compared to food and livelihood functions. The carbon footprint is but lower than observed by Tesfahun (2018). This is a result of higher milk yield per cow in comparison to his findings. On cow basis emissions went up with the use of concentrates and increased feed intake but emissions decline as animal productivity increases and this was confirmed by Gerber et al. (2011).

Table 24:Allocation factors and carbon footprint [kg CO_2 eq/litre]

	WA1	WA2	WA3	ES1	ES2	ES3	ES4
Food	4.40	1.10	0.63	0.44	0.05	0.53	0.95
Economic	3.25	1.74	2.02	4.03	1.17	1.67	2.57
Livelihood	3.62	0.03	0.08	0.16	0.01	0.03	0.12

As a result of low milk yield in farm WA1, the amount of milk that is consumed at home constitute a high proportion of the total milk yield hence the high allocation of emission to livelihood in comparison to the rest of the farms.

Other environmental costs

Manure is sometimes dumped within the residential areas or very close to the lake as shown in figure 20 causing environmental concerns such as eutrophication.

Figure 19: Manure transportation to the dumping sites

Manure dumped near lake Ziway

Manure dumped within residential areas

4.4 Partial budget scenarios

To assess the economic and environmental impact of each climate smart practice, different scenarios of cost and returns gained by implementing different climate smart practices and their impact on GHG emissions. Some of the climate smart practices have already been implemented whilst others are the proposed practices.

Scenario 1: Adoption of the Holstein-Frisian breed

This practice has already been implemented with farmers in West Arsi having 97.8% and East Showa 97.2% Holstein Frisian breed and that is quite high in comparison to findings by Tesfahun(2018). The cost consideration is the feed cost as the main variable and the feed intake by the Arsi breed is estimated at 50% of the current feed intake by the Holstein-Frisian breed. Milk yield per day is estimated at 2 litres as observed by Van Geel et al (2018) and Brandsma (2013). This will result in saving on the feed bill however, the milk yield drops resulting in reduced milk revenue. The feed cost was captured from the farm budget in table 12.

Table 25: Partial budget for the adoption of the Holstein-Frisian breed [Etb]

Variable cost	WA1	WA2	WA3	ES1	ES2	ES3	ES4	Average
Extra feed cost	-12000	-360000	-120000	-180000	-666600	-350000	-237600	-275171
Total variable cost	-12000	-360000	-120000	-180000	-666600	-350000	-237600	-275171
Extra milk revenue	25920	226800	103680	103680	362880	194400	84240	157371
Gross margin	37920	586800	223680	283680	1029480	544400	321840	432543
% increase in Gross margin	68%	39%	46%	37%	35%	36%	26%	41%

The milk yield and emissions for the Holstein-Frisian are based on the fieldwork whilst the Arsi breed are based on literature review according to Brandsma et al. (2013) and Van Geel et al. (2018). Farms with low milk yields also have a lower reduction in emissions through this intervention

Table 26: Enteric emissions after the adoption of the Holstein-Frisian breed. [kg CO_2 eq/liter]

	WA1	WA2	WA3	ES1	ES2	ES3	ES4	Avarage
Milk yield	1080	11340	5400	4320	16200	7500	4800	7234
FPCM	1079	11329	5395	4316	16184	7493	4795	7227
Enteric emission (Arsi breed)	7.5	5.8	5.0	10.4	8.4	8.3	7.7	8
Enteric emission (Holstein-Frisian)	2.32	1.23	1.45	3.49	1.24	1.31	2.37	2
% reduction in emissions	-69%	-79%	-71%	-66%	-85%	-84%	-69%	-75%

As a result of the drop in milk yield enteric emissions increase. Therefore, the investment in Holstein-Frisian cross breed reduces GHG emissions whilst the feed goes up although the increase in milk yield increases the gross margin as shown in table 25. The FPCM was kept at 4% fat and 3.3%.

Scenario 2: Partial budget for replacing male animals with female

A total of four farms in this study kept male animals and if these farmers were to replace the male animals with cows and the cows producing at current herd average. ES2 keeps oxen for ploughing the value of hiring a tractor will be factored in together with cost related to feeding extra dairy ration to the milking cows will be included. The variable cost and gross margin were calculated using equation 1-5. The rest of the farmers in East Showa with the exception of ES2 do not give Alema Koudijs concentrate feeds, therefore, the feed is kept as is as shown in table 26.

Table 27: Partial budget for replacing male animals with female[Etb]

	ES1	ES2	ES3	ES4	Avarage
Variable cost	374,680	1,428,700	717,625	490,200	579,359
Dairy ration cost	0	197,100	0	0	28,157
Ploughing cost		144,000			144,000
Total variable cost	374,680	1,769,800	717,625	490,200	628,088
Milk revenue	485,100	2,299,000	950,400	601,380	856,025
Additional milk revenue	156,816	689,700	242,550	225,498	187,795
Other revenue	0	0	0	0	0
Total revenue	641,916	2,988,700	1,192,950	826,878	1,043,820
Gross margin	267,236	1,218,900	475,325	336,678	415,732
Current gross margin	246,420	1,366,500	267,775	148,180	385,880
Extra gross margin	20,816	-147,600	207,550	188,498	29,852
% increase in gross margin	8%	-12%	44%	56%	24%

Based on the increase in cows the milk yield went up together with the FPCM and this directly reduced by 26-38% the enteric methane emissions per litre of milk in East Showa whilst maintaining the same herd size as shown in table 27. This was also observed by Weiler et al., (2014). All the emissions in the table are in kg of CO_2.

Table 28: Impact of increase in milk yield on enteric emissions. [kg CO_2 eq/litre]

	ES1	ES2	ES3	ES4	Avarage
Milk yield	12848	110189	47507.03	15633	36885
Additional milk	2376	5225	3675	2891	3542
Total milk	15224	115414	51182	18524	38909
FPCM	15209	115299	51131	18505	38870
GHG emissions before	3.49	1.24	1.31	2.37	1.92
GHG emissions (after)	1.54	1.01	1.15	1.17	1.41
% reduction in GHG	-38%	-30%	-26%	-37%	-19%

Scenario 3: Composting all manure produced annually

At the time of fieldwork, no composting was observed and only farmers with crop production were using manure as a fertiliser but it was not composted, it was stored in solid storage. To capture the value of manure the manure application rate of 5 tonnes per hectares was used together with fertiliser application rates based on information from key informant 1. The extra costs involved are shown in table 28.

Table 29: Partial budget for composting [Etb]

Partial budget for composting	WA1	WA2	WA3	ES1	ES2	ES3	ES4	Average
Extra labour cost@1200 etb per farmhand	2400	4800	2400	4800	7200	4800	2400	4114
Manure revenue	4872	27671	14926	24927	72277	67555	17972	32886
Return on investment	2472	22871	12526	20127	65077	62755	15572	28771
Return on investment %	51%	83%	84%	81%	90%	93%	87%	81%

Farmers by adopting composting can increase revenue and gross margin as shown in table 28 although the lack of a market for compost can be a demotivating factor for farmers to invest in composting. Composting manure reduces GHG emissions as shown in table 29. Farmers, livestock specialist, development agents and the translator (from a research institute) all named the solid storage system a compost which may be a gap that needs to be addressed by the farmer research group and Adami Tulu research centre . Adoption of composting manure and using it as a fertiliser can save money for the farmer, improve soil fertility, reduce the need for artificial fertiliser at the same time preventing dumping of manure within the residential areas as it poses a health hazard. All the emissions in the table are in kg of CO_2.

Table 30: Direct and indirect emission during composting. [kg CO_2 eq/liter]

	WA1	WA2	WA3	ES1	ES2	ES3	ES4	Average
Emission direct + indirect (before)	519	3276	1383	2895	8394	6260	2087	3545
Emission direct + indirect (composting)	442	3495	1457	2464	7144	6677	1776	3351
Reduction in emissions	-77	218	74	-431	-1250	417	-311	-194
% Reduction in emissions	-15%	7%	5%	-15%	-15%	7%	-15%	-6%

ES3, WA2 and 3 had an increase in GHG emission and they all have part of their manure managed in an anaerobic biogas digester. In this case, the anaerobic digester is more effective in reducing GHG emissions from manure management in comparison to the solid storage and composting this was confirmed by Velinga et al., (2011).

Scenario 4: Adoption of anaerobic biogas digester for all manure produced

A partial budget was also done to come up with economic returns a farmer stands to benefit if they install biogas digester. An estimate was done to come up with the size of biogas digester that can handle all the manure produced and all the cost involved as shown in table 30. The digester does not necessarily have to be at the farm, the farmer can have partnerships with institution and households that are interested in having the biogas installed. The table below shows cost relating to the biogas and formulas given in 4.1.4 was used to calculate the cost. Over a lifespan of 20 years.

Table 31: Cost of installing and running the biogas [Etb]

	Cost of investment	Life span	Depreciated cost	Maintenance 2%	Interest 11%	Value of building
WA1	40000	20	2000	80	2200	4280
WA2	80000	20	4000	160	4400	8560
WA3	60000	20	3000	120	3300	6420
ES1	60000	20	3000	120	3300	6420
ES2	180000	20	9000	360	9900	19260
ES3	120000	20	6000	240	6600	12840
ES4	60000	20	3000	120	3300	6420

Table 32: Partial budget for investing in a biogas[ETB]

	WA1	WA2	WA3	ES1	ES2	ES3	ES4	Average
Additional cost	40000	80000	60000	60000	180000	120000	60000	600000
maintenance cot@2%	800	1600	1200	1200	3600	2400	1200	12000
new total cost	40800	81600	61200	61200	183600	122400	61200	612000
Electricity bill/month	600	0	1200	1200	16824	1200	6000	27024
Value of gas generated	600	0	2400	1800	50472	3600	12000	70872
Useful years	20	20	20	20	20	20	20	140
Total value of gas	12000	0	48000	36000	1009440	72000	240000	1417440
Return on investment	-28800	-81600	-13200	-25200	825840	-50400	178800	805440
% Reduction in emissions	-42%	-23%	-5%	-10%	60%	-19%	121%	12%

According to the calculations in table 31, the return on investment is positive for farms that already had high electricity consumption such as East Showa 2 and 4. This may be one of the reasons limiting the adoption of the practice in farms that have low electricity costs. Anaerobic digester had a significant impact on direct and indirect emissions from manure management as shown in table 32. The emissions are even lower than when the same amount of manure is composted (table 29). ES3, WA2 and 3 have lowe GHG emission reduction because part of their manure is already managed through the anaerobic biogas digester.

Table 33: Direct and indirect emission during anaerobic digestion [kg CO_2 eq/liter]

	WA1	WA2	WA3	ES1	ES2	ES3	ES4	Average
GHG emission before	519	3276	1383	2895	8394	6260	2087	3545
GHG emission with composting	309	2446	1033	1725	5001	4674	1243	2347
Reduction in emissions	-210	-830	-350	-1170	-3393	-1586	-844	-1198
% Reduction in emissions	-40%	-25%	-25%	-40%	-40%	-25%	-40%	-34%

Scenario 5: Using a bull instead on artificial insemination at West Arsi 2

Although all farmers depend on AI some keep bulls as back-up since the AI service is not always available. All farmers in West Arsi don't keep bull and keeping bulls will cost them money feeding the bulls even when the bull is sold for 65 000etb (divided by ten since the cost are captured for one year only) as shown in table 33. Farmers in East Showa already have bulls were not included in this calculation.

Table 34: Partial budget for investing in a bull instead of AI [ETB]

	WA1	WA2	WA3	Average
Additional cost	6600	27310	22000	18637
Current variable cost	39436	756550	248325	348104
Total variable cost	46036	783860	270325	366741
Current revenue	108671	1104209	503718	572199
Sell of bull after 10years	6500	6500	6500	6500
Total revenue	115171	1110709	510218	578699
New Gross margin	69134	326848	239893	211959
Current GM	69234	347659	255393	224095
% reduction in gross margin	0%	-6%	-6%	-4%

Keeping an extra bull will also increase GHG emissions and as a result of adding an extra animal that does not produce milk as was observed in the scenario when male animals were replaced by milking cows.

Scenario 6: Straw treatment with effective micro-organism (EM)

To come up with a partial budget for straw treatment all dry crop residues in table 14 above were taken into consideration. The price of EM cost 30 ETB per litre and the daily requirement is 2 litres per 120kgs of crop residues. Each litre of EM2 is diluted by 16 litres of water and a litre of molasses is added them mixed with the straw and this increases milk yield by 1.5 litres per day per cow through improved digestibility of straw (Kitaw et al., 2016). The fixed cost, variable cost, and gross margin were calculated using equation 1-5 and the total cost are shown in table 34.

Table 35: Partial budget for straw treatment with effective micro-organism (EM)[ETB]

	WA1	WA2	WA3	ES1	ES2	ES3	ES4	Average
Total crop residue	7665	63510	40515	59860	220825	101288	38325	75998
Cost of molasses	1405	11644	7428	10974	40485	18569	7026	13933
Price of EM	1916	15878	10129	14965	55206	25322	9581	19000
Ensiling bunkers	5000	10000	5000	10000	15000	12000	7000	9143
Extra labour	1200	2400	2400	2400	3600	3000	1200	2314
Total additional cost	9522	39921	24957	38339	114291	58891	24808	44390
Extra revenue	17010	204120	85050	71280	267300	123750	93600	123159
Gross margin	7489	164199	60094	32941	153009	64859	68793	78769
% increase in Gross margin	11%	47%	24%	13%	11%	24%	46%	25%

Straw treatment directly improves the digestibility of crop residues which in turn also decrease the enteric emissions (Kitaw et al., 2016). Though the improvement in digestibility was not ascertained by using an increase in milk yield enteric emissions also went down. This trend was also observed by Weiler et al., (2018).

Table 36: Effect of straw treatment on enteric methane emissions. [kg CO_2 eq/litre]

	WA1	WA2	WA3	ES1	ES2	ES3	ES4	Average
Increase in milk yield	810	8505	4050	3240	12150	5625	3600	5426
FPCM straw treatment	809	8496	4046	3237	12138	5619	3596	5420
FPCM before straw treatment	3500	49773	18675	12835	110079	47460	15617	36849
Total FPCM	4310	58269	22721	16072	122217	53079	19214	42269
Enteric emission(after)	1.59	1.08	1.04	1.77	1.17	1.28	1.39	1.33
Current enteric emissions	2.32	1.23	1.45	3.49	1.24	1.31	2.37	1.92
Reduction in enteric emissions	-73%	-15%	-41%	-172%	-7%	-4%	-99%	-59%

Straw treatment reduced enteric methane in all the farms. Straw treatment is done on dry crop residues so the farmers that include green corn stem and Napier grass had less straw treated hence the lower impact on GHG enteric emission.

Figure 19: Straw treatment in plastic container or silo bunker

4.5 Effects of GHG emissions on dairy farming system

High enteric emissions in dairy farms can be used as an indicator for inefficiencies in the production system especially as a result of the feeding of poor quality roughage as observed in WA1 and ES1 in table 22. The same farms also had the lowest milk yield as shown in table 5 therefore reduced gross margins. GHG emissions from manure management system can increase based on the choice of feed, low-quality feed lead to high enteric emissions (table 22) and high VSE rate (table 23) and increased manure output. GHG emissions can also mean extra cost on the dairy farming system, WE2 had the highest transport emissions as a result of the long distance from the source of the feed as shown in figure 13. In this study, an increase in GHG emissions is directly related to a reduction in economic returns. On cow basis emissions went up with the use of concentrates and increased feed intake but emissions decline as animal productivity increases and this was confirmed by Gerber et al., (2011) resulting in lower emissions per litre of milk. Farms with high carbon footprint also lower profit per litre.

Effect of GHG emissions on the dairy farming system is also a result of the contribution of dairy GHG emissions to climate change as shown in figure 6 (Rojas-Downing et al., 2017). A farmer in West Arsi who depend on water from a stream reported that the stream only had flowing water in some parts of the year just after the rainy season and this affects the quality and quantity of water he has access to. However, despite water shortage in West Arsi farmers do not have water harvesting structures and this leaves the farmers vulnerable to water shortage. West Arsi urban farmer reported when tap water is not available they buy water at 6 etb for 20 litres. As a result, the animals have limited access to water yet with global warming the cows require 2-3 times (Gerber et al., 2013) more water than before. East Showa is more arid (midland-lowland) hence the farmers have already put up back-up water reserves unlike in West Arsi (highland). Availability of native grass hay was limited hence the dependence on crop residues as the main form of roughage. However, the farmers and the animal health expert did not report any new disease in the area or any form of weather-related stress such as heat stress.

4.6 Inclusiveness and resilience in the dairy farming system

Inclusiveness

The farmers vary in age ranging between 29 and 50 years old, however, only one woman was included in the research and their education background ranges between grade 8 and diploma level. Based on key informant 3 female farmers are common in the rural areas, especially in female-headed households. The farmers in the study are either model/lead farmers or members of a farmer research group and this gives them access to knowledge and training. Access to resources and training were mainly based on the interest of the farmer to join the farmer research group and the ability to afford private services in the absence of government-subsidized service. The female farmer had access to resources although the control seemed limited. None of the farmers in the study have approached the bank for a loan though some have mentioned the traditional social safety net such a *Ekub* (rotating savings and credit association) and *Idir*. Both *Ekub* and *Idir* are flexible and more accessible in comparison to banks and they require minimal paperwork.

The farmers in this study are not exactly the resource-poor and six of them are located in urban areas, therefore, they have minimum access to government extension service since it targets rural farmers as the government tries to improve the productivity of resource-poor farmers (key informant 3, Zijlstra et al., 2015). The rural farmer has access to government extension service and also benefited from training and resources from SNV-EDGET program. Family labour was mainly the farm owner managing the farm whilst the rest were male hired farmhands since the farmers thought the workload was too much for women. None of the farmers are members of a cooperative and each farmer has to find a market for milk and supply of feeds. There was no evidence of the wives' involvement in dairy farming in terms of participation, access, and control of profits and decision making on the running of the business or taking part in the dairy daily chores (based personal conversations with 4 of the wives). The female farmer was involved in all the dairy daily chores and also the marketing of milk, decisions making on the running of the business. The husband had a supporting role in all the activities especially feed formulation based on his work experience at Adami Tulu research centre.

Resilience

All farms depended on outsourcing feeds making the farmers vulnerable to price fluctuations and feed shortages. Even for farmers that are located in the same town, they all gave different prices from each other and from the ones the researcher obtained from the feed agents. The role of the farmer research group played a big role in urban dairy farmers in building the capacity of the farmers through the innovation and information sharing platform since there is limited extension service. All farmers have an entrepreneurial approach within the dairy farming business with multiple revenue streams (milk, live animal sales) and had other businesses to supplement their income. This was also a way of spreading risk, furthermore, two farmers in East Showa are making a plans to do vertical upgrading of the current business model such that they can be involved in producing, collecting, processing and retailing of milk. Milk was marketed both in the formal and informal market with farmers citing better prices at farm gate, however, because of the fasting season they had so sell the milk to the processor as demand for milk at farm gate drops also observed by (Zijlstra et al., 2015).

Farmers in East Showa had water harvesting structures and improved housing for their cows to make sure cows have the optimum environment for maximum productivity. Adoption and implementation of technological innovations are slowly taking place with one of the farmers having milking machines. Adoption of straw treatment is still very low together with fodder production and use of legume plants and these are missed opportunities in improving resilience to poor quality feed. Linkages with necessary stakeholders such as financiers, processor, input suppliers, and agriculture information and knowledge sharing are a weak link both in East Showa and West Arsi. The farmers do not invest in long term relations or contractual agreements yet they are necessary for managing risk especially considering the farmers are going for an entrepreneurial approach in their businesses. Horizontal linkages were not evident whilst the main vertical linkage was with the milk collector and processor or milk kiosk. ES3 had a business to business linkage with a hotel that improved waste management on the farm.

4.7 Business models

This section focuses on the social, economic and environmental structures in the dairy farms based on the researcher's observation and farmer feedback during the focus group discussion and how the structures can be improved. This section also covers sustainability in the dairy farming systems though sustainable business models that are inclusive and resilient

The economic layer of the business canvas shows the economic cost and observed in the dairy farms as highlighted in black. The text in red show other cost and returns the farmer can incur in the process of implementing climate smart practices. This is very important in identifying how the business can align profit and purpose to support climate smart oriented value creation in order to achieve the triple bottom line instead of focusing on economic profit only. The information in this section is based on the production performance cost price and gross margins in section 4.1.4 and feedback from the focus group discussions.

Figure 20: The economic layer of the triple base business canvas model

Economic

Key partners
-livestock agency
-Extension service
-Adami Tulu research centre
-Cooperative
-input suppliers
-Milk collectors
-milk processors
-Milk retailers
-Other farmers
-NGOs
-Farmer research group

Key activities
-Dairy farming activities
-Manure management systems
-Marketing of milk and distribution of milk
-Fodder production with legumes and grasses
-long term input and output partnerships
-composting and anaerobic digesters
-disease control e.g mastitis

Key resources
-Land, exotic cross breeds cows,
-Finance(savings)
-inputs e.g. manure, sexed semen, fertiliser
-Choppers and silage bunkers
-Improved cow barns with ventilation, easy water access, drainage system and bedding
-Innovation platforms such as farmer research groups
-Milking machine and bedding for the cows
-improved nutrition and mineral supplements
-staff that include both men and women

Value proposition
Main product
–Secure supply of improved quality and quantity of milk produced through climate smart and improved hygienic practices
By-product- meat, manure, fodder , crop -residues and other crop products
Vision
-Dairy production system that captures ecological, social and economic value through creation of shared value

Customer relationship
- Trust based relationship between dairy farmer and milk processor
-Buyer-seller contractual relationship for both milk and input supply especially feed supply

Channels
-Informal market through farm gate sales , hotels, restaurant and milk bar retailers
-Home consumption
-local traders and retailers
-Formal market with a milk quality management system and cooling system

Customer segments
-Institutional consumers e.g. restaurants , retailers and cafes
-Farm gate sales to the neighbours
-Formal market through the cooperative that sells directly to processing companies

Cost structure
-Variable costs 39436-1428700 ETB (feeds have the highest contribution)
Fixed cost 72388-721824ETB
Overall cost 111824-2150524 ETB
-Feed supplements and specialised transportation with refrigeration
-Marketing, processing, packaging cost
-adoption of composting and bigger anaerobic digester
-green energy eg solar and bigger anaerobic biogas digester

Revenue streams
Main revenue- Milk= 103270.7 - 2299000 ETB
Other revenue streams
-Live animal sales=0- 480000 ETB
-Other crop products (wheat, teff, barley, maize, coffee, chat and Fodder(Napier))
-Manure sales 5400-16200 ETB
-biogas energy sales through partnership with neighboring households

Figure 21: Environmental layer

The environmental layer in this study is based on the life cycle assessment of FPCM from cradle to farm gate. All environmental impacts of dairy farms will be considered in addition to the GHG emissions. This is important in highlighting weak areas in the current business models such that farmers make informed decisions as they implement climate smart practices. Figure 23 shows the environmental cost and benefits of the dairy farms based on research findings in section 4.3 complemented by feedback from the farmers and the observations by the researcher.

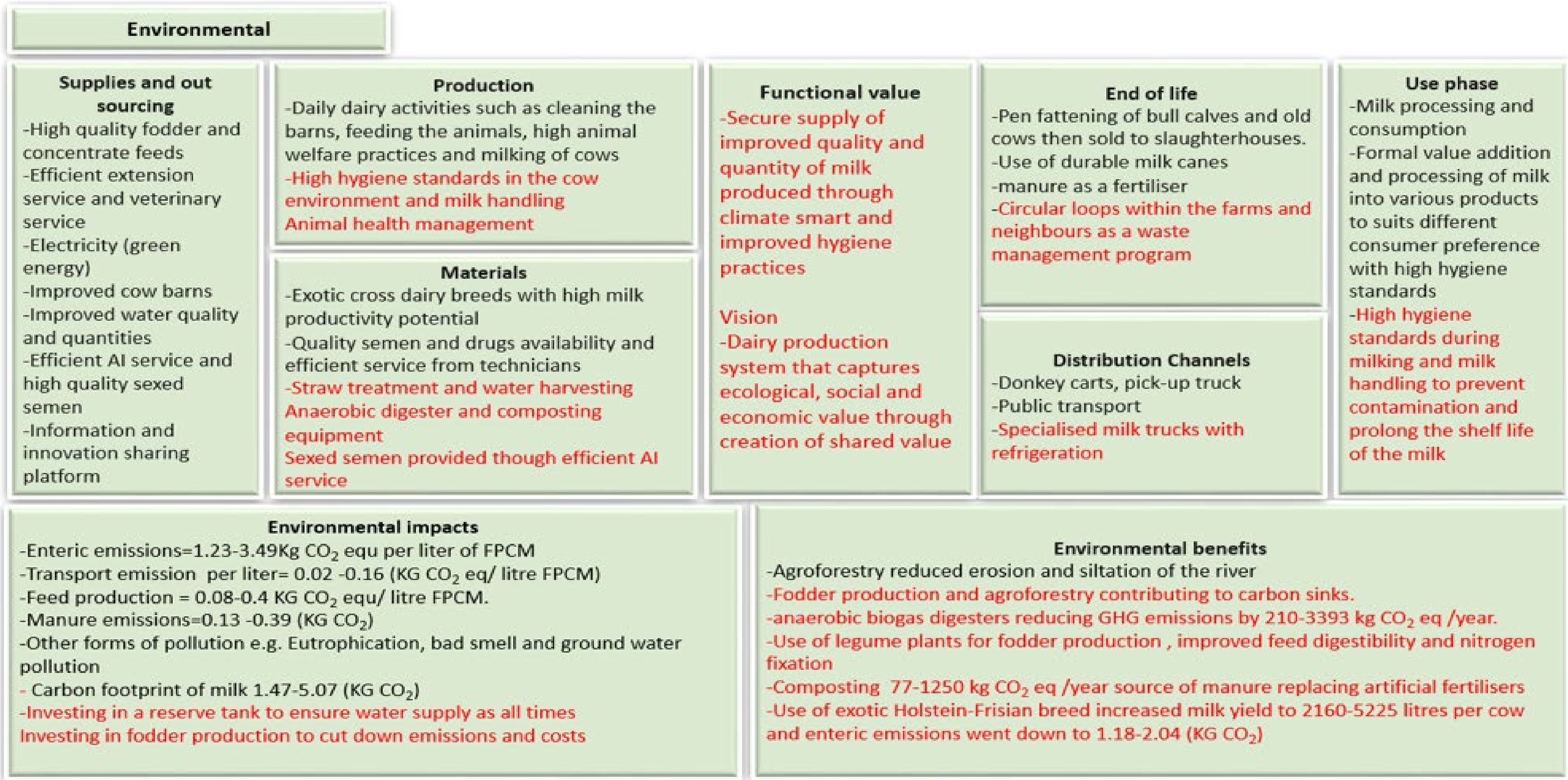


Figure 22: Social layer of the triple base canvas model.

In an effort to build climate smart oriented dairy farming system inclusions of social value creation is important. The stakeholder and shareholder approach was used in this study to assess the social impact of dairy farms. An assessment of the current horizontal and vertical linkages in the dairy farming system and the dairy value chain was made so as to find out how shared value is created. In this case, the shareholders are business partners and employees whilst the stakeholders are a community, customers, input suppliers, and Adami Tulu research centre. The non-human stakeholders is the natural ecosystem according to Joice (2016). Instead of a farm simply capturing and creating value it also creates shared value this is key in building sustainability within the dairy farming systems. The social layer of the business canvas below shows the feedback from the farmers and researcher observation and how the farmers can create shared value whilst also capturing value as shown in figure 24.

Social

Local communities
-Dairy chain actors
-Internal and external consumers of dairy products
- Chain supporters e.g. farmer research group,
-Employees
-Neighbours
-Other consumers of the dairy by-products

Governance
-The farmer manages the farm activities, organizing farm structure and decision-making and engaging and linking with key stakeholders and shareholders in the dairy value chain

Employees
- Source of employment for both urban and rural youth
- Room for personal development in the work place through internal and external training programs.
- Community engagement through shared value or corporate social responsibility

Social value
-Secure supply of milk (and meat) for improved nutrition
-Dairy farming as a form of both urban and rural entrepreneurship
-Dairy farming as a source of manure for the crop production system

Vision

-Dairy production system that captures ecological, social and economic value through creation of shared value

Societal culture
-Increased consumption of dairy and meat products
-secure supply of milk and meat from dairy farms
-Improved nutrition through dairy products that are high in protein
-Increased participation of women and youth in dairy farming
-Use of manure as the main form of fertiliser

Scale of outreach
- Linkages and partnerships within the community as a way of improving manure management system
-Shared value and CSR between dairy farms and the local community
-linkages through contractual relationships with inputs suppler and buyer

End –user

-Good nutrition and diversified meal options through different dairy and meat products
- Ready source of manure that can be used to improve crop yield through improved soil carbon content, biodiversity and fertility

Social impacts
-Opportunity cost of using the land for other forms of production
-Manure management system still need to be improved to prevent ground water pollution.
-Hygiene standards need to be enforced to improve animal living conditions, milk quality and staff working conditions
-Disease control and poor control of antibiotic usage and storage
-Need for protective clothing for farm workers
-Improved relations between stakeholders and shareholders
- Fair value share, shared value and value capturing

Social benefits
-Employment opportunities for the youth including women
Improved income and livelihood for dairy farmers and other dairy chain actors
-Improved nutrition for the dairy farmers and the community
-Personal development for the dairy farmers through different training programs and farmer research group.
-Farmer as a lead farmer in his community can lead in the adaptation and diffusion of climate smart dairy farming
-Income source for women through dairy farm ownership in urban areas
-genuine participation by women at all levels in the dairy farm and value chain

CHAPTER 5 DISCUSSION

This chapter provides a discussion of results from the study and answers to the sub-questions.

5.1 Environmental and economic costs in dairy farms

Economic cost

The main economic cost was the feeds constituting at least 60% of all variable cost mainly because the farmers outsource almost all of their feeds and they supplement with concentrates add extra costs considering concentrates are more expensive than roughages. The farmers are also investing in improved housing, artificial insemination, cow maintenance such as routine checks by a vet, hoof trimming and dehorning. The studied farms have 97.8% in West Arsi and 97.2% in East Showa is the Holstein-Frisian breeds. Based on Tesfahun (2018) who observed 89% Holstein-Friesian breed showing an increase in the number of exotic crossbreeds. Keeping bulls as a backup during breeding cost more both environmentally economically. Use of private AI service is costlier but reliable in comparison to the government service. Urban farmers without land have to pay to dispose of manure although the fee charged is the collection and transportation of manure and not the polluter pay fees. All farms had permanent hired labour and this adds to the fixed cost. Electricity and water bills were quite low, however, because they are not always available this increased cost for example farmers in West Arsi have to buy water and this adds to the cost. Use of machinery such as tractors and combine harvester during feed production increase off-farm cost whilst the use of a chopper in East Showa 1, 2 and 3 and a milking machine in East Showa 2 added to the economic cost. East Showa 2 and 4 have high electricity as a result of milking machine and choppers whilst East Showa 3 has refrigerators cooling the milk. Feed remains the highest contributor to the farm variable cost.

Environmental cost

Although current milk yield is higher than the indigenous breeds, it is still lower than the full potential of the Holstein-Frisian breed, therefore, the GHG emissions obtained by maximising milk productivity as observed in the partial 23 for use of exotic breeds has not been fully realised. It was observed in this study that the use of concentrates and straw treatment increase the economic cost for the farmer, however, the improved rations have a direct impact of increasing milk yield and reducing enteric emissions through improved digestibility. The main environmental cost was methane emissions from enteric fermentation being the highest followed by feed and lastly manure (figure 17), however, the emission per litre is much lower than observed by Tesfahun (2018) and this is because they were urban farms and not very representative of the dairy farms in the milk shed. Even with supplementary concentrates digestibility is still low and this increases volatile solids excreted, IPCC (2006) confirms that low digestibility in feeds leads to higher VSE, therefore, more manure produced causing environmental cost.

Fodder production has both environmental and economic cost attached to it but in this case, since the farmers used manure, it became an environmental and economic benefit. Tedesse et al. (2018) also observed the positive environmental impact of using manure as a fertiliser in comparison with artificial fertiliser. Use of solid storage instead of composting or anaerobic digester was both an economic and environmental cost as a result of GHG emissions as shown in the anaerobic and composting scenario 4 in section 4.4 that reduced the emissions from manure management also confirmed by IPCC (2006). Use of the anaerobic digester and composting have a significant impact in reducing GHG emissions as a result of their ability to reduce CH_4 and N_2O that have very high global warming potential as confirmed by UNFCCC (2019). The high cost of investing in anaerobic biogas digester could be the reason for adoption is low.

However, for farmers that have high electricity bills investing in biogas powered machinery can make the investment worthwhile. Other environmental and social cost includes eutrophication of water bodies as a result of leaching and runoff of nutrients in the manure (Steinfeld et al., 2006) as a result of the storage of the manure in the solid storage. In dairy farming systems separating economic and environmental cost is very difficult as they are interconnected. Enteric emissions are the highest in comparison to feeding and manure emissions, managing the nutrition through improved rations and fodder production is the starting point if the farmers are to build sustainable climate smart farming systems especially considering feed remains a weak link in the study area.

5.2 Costs and revenue streams within the dairy farms

In the seven farms, milk was the main revenue ranging between 84012 and 2421744 ETB annually. Also observed by the level of investment on the farms show that the farmers are taking dairy farming from an entrepreneurial perspective with the goal of increasing revenue. Focusing on economic profit limits the creation of shared value and the carbon footprint was 1.42 and 4.57 kg CO_2 eq per litre of milk.

- Animals sales were the next highest revenue earner even more so for farmers in East Showa that keep male animals. This practice reduced income by 26 and 56% than if they were to replace male animals with milking cows only as shown in the scenarios in 4.4.
- The use of composted manure as a fertiliser could be an income-generating activity earning the farmer between 2472-67077etb per year (scenario in 4.4), however the lack of market and the fact that most urban farmers do not have any land make manure management a cost for the farmers.
- Investing in rations with higher digestibility through use of concentrates, legume fodder and crop residue treatment are necessary for complementing the investment in AI such that the Holstein-Frisian cows can produce at their full potential whilst at the same time reducing the volatile solid excretion rates and enteric emissions. This was also highlighted by IPCC (2006).

All farmers had other businesses such as crop production, retail, restaurants and milk processing and retailing to increase their income. Although this improves farmer resilience, it may prevent the farmer from taking dairy farming as a full-time business and this may reduce the farmers' overall investment in the business. Other revenue streams can be the reason the farmers never applied for loans from banks as the other businesses are financing the dairy farm whenever necessary. In the dairy, farm milk contributes the highest to farm revenue.

5.3 Seasonal feed variation, production, feed cost, and GHG emissions

Farmers in both regions have zero-grazing units and depend on crop residues as the main roughage source also observed by Tezera (2018), and they are abundant during the harvesting season thereafter the crop residue prices go up during the season of scarcity. As a result, farmers stockpile on the roughages such that they do not run out of feed or buy when it is now expensive. Although it makes sense to stockpile on roughages they lose their quality especially if stored outside and this can result in deterioration of the quality of feed and an increase in GHG emissions. It also locks up money in the feed yet it could have been invested somewhere else. Farmers also invest in concentrates to boost the nutritive value and digestibility of the ration and concentrate, however, the amount used and the choice of concentrate was different between farms and so were the milk yields and enteric emission. As farmers try to keep the feed cost low, use of cheaper concentrates was observed at ES1 and this resulted in higher enteric methane emissions

The lack of labels and quality standards on the concentrate bags can also result in farmers paying for the cheap quality without knowing as shown by farmers supplementing with concentrates yet their milk yield varies. Feed availability and quality remain an area that is affecting farm profitability and GHG emissions as a result of its central role in affecting milk yield and manure excreted.

5.4 GHG emissions per climate smart practice

The farmers in the study fed crop residues supplemented with concentrated and this had the direct effect of improving the digestibility of the feed as shown by the low enteric emission in table 36. The improved digestibility also reduced the volatile solid excreted ad show by the low methane emission in all the farms. Anaerobic biogas digester and composting reduced GHG emission significantly with biogas being more effective than composting. Solid storage is the least effective in reducing emissions based on the scenarios and fieldwork. Use of exotic breeds reduced emissions significantly.

Table 37: GHG emissions per climate smart practice[KG CO_2 per liter]

Farm	Concentrate usage	Improved digestibility	All feed transport emission	Emission allocated for crop residue	Manure management system	Emission CH_4 & N_2O per liter
WA1	2.32	0.02	0.03	0.16	Solid storage	0.17
WA2	1.23	0.02	0.03	0.03	Anaerobic digester & solid storage	0.09
WA3	1.45	0.03	0.03	0.05	Anaerobic digester & solid storage	0.10
ES1	3.49	0.03	0.03	0.09	Solid storage	0.26
ES2	1.24	0.01	0.03	0.03	Solid storage	0.09
ES3	1.31	0.02	0.03	0.03	Anaerobic digester & solid storage	0.16
ES4	2.37	0.02	0.03	0.06	Solid storage	0.15

Other climate smart practice observed but the emissions were not quantified and these include fodder production and agroforestry as they contribute towards the creation of carbon sinks. Manure management systems such as separation of cow dung and urine through the gentle slope on the floor certainly reduce N_2O volatilization and this is important considering that N_2O has a very high global warming potential. According to Vellinga (2019), this practice can reduce ammonia formation by 75%. Water harvesting was observed in East Showa, therefore, the cows had better access to water and the water is important in maximising on milk yield. The water quality check or water treatment means the water may not be of potable quality and this is not good for the cows. Although not direct herd health management contributed to the intensification of production per cow.

5.5 Economic and environmental returns per climate smart practice

Based on the scenarios 4.4 in table 37 was designed to show the economic and environmental impact of each climate smart practice in percentages. Use of Holstein-Frisian breed increased the gross margin by 55-217% whilst the enteric emissions went down by a minimum of 75%. Composting increased the gross margin through an extra revenue stream and the emissions also went down by 15% but only for farms that did not have biogas before. For farms with biogas, emissions went up by 5-7%. Of all the manure managements systems observed the anaerobic biogas digester was most effective in a reduction in emissions by 25-40% although the return on investment had a negative ranging between 5-42%. Farmer

ES2 and 3 that have high electricity cost the investment have positive returns. Having extra female cows also had a direct increase in milk yield as shown in section 4.4.

Table 38: Economic and environmental returns

		WA1	WA2	WA3	ES1	ES2	ES3	ES4
High yielding exotic breeds	Additional Gross margin [ETB]	37,920	586,800	223,680	283,680	1,029,480	544,400	321,840
	Enteric emission (Holstein-Frisian)	-69%	-79%	-71%	-66%	-85%	-84%	-69%
Composting	Additional Gross margin [ETB]	2,472	22,871	12,526	20,127	65,077	62,755	15,572
	% Reduction in emissions	-15%	7%	5%	-15%	-15%	7%	-15%
Biogas	Additional Gross margin [ETB]	- 28,800	-81,600	- 13,200	-25,200	825,840	- 50,400	178,800
	% Reduction in emissions	-40%	-25%	-25%	-40%	-40%	-25%	-40%
Straw treatment	Additional Gross margin [ETB]	7,489	164,199	60,094	32,941	153,009	64,859	68,793
	Reduction in enteric emissions	31%	12%	29%	49%	6%	3%	42%
Female only herd	Additional Gross margin [ETB]				20,816	-147,600	207,550	188,498
	% reduction in GHG	0%	0	0	38%	30%	26%	37%
AI	Additional Gross margin [ETB]	- 19,275	- 62,847	- 87,642	- 56,588	0	0	0

5.6 Inclusiveness and resilience in the dairy farming system

Inclusiveness in the study area is shown by two young farmers, both are lead farmers. Both have fodder production whilst the rural West Arsi farmer has a circular dairy farming system.in both regions men dominated the ownership and as hired labour hence excluding women. Though banks offer loans none of the farmers took loans and this may mean there are limited opportunities for other individuals such as women and youth to venture into dairy farming. The role of women seemed functionary though on the ground it wasn't evident therefore they have limited genuine participation in the farms. Inclusions of the internal and external stakeholders varied with farms WE 3 is engaging the community through shared value whilst the rest focused on capturing economic profits only. All farmers have chosen to be in the farmer group as a way of having access to information sharing platform since there is no extension service. Female representation in the study was only one farmer running the business together with her husband. Both male and female farmers had equal access to the farmer research group. Farmers in the study preferred male hired labour since they felt the job was too much for women. WE3 is including the community by selling milk to the household surround the farm at below-market prices as part of corporate social responsibility and also business to the business partnership by giving out manure for biogas generation at Haile hotel. The current situation in the dairy farms offers limited opportunities on the farm as it is biased towards men.

Resilience

The farmers operate at an individual basis yet if they were to make business partnerships through vertical and horizontal linkages it could reduce the economic, social and environmental cost that comes with the dairy business. Most of the structures observed focused on short term adaptation solutions in building resilience for example storage of large amounts of feed yet fodder production and silage making could have better long-term results. Investment in animal health and high producing exotic breeds and diversified revenue streams enabled to manage and spread risk but with feed being a weak link reduces the resilience of dairy farms to feed shortages. The lack of collective action through organisations such as a cooperative and long term relationship or contractual agreements leaves the farmers vulnerable to input price fluctuations. Although risky the sale of milk at the farm gate enables the farmer to increase their value share since farm gate prices are higher than those offered by kiosks and processor. Lack of processing capacity results in farmers being price takers of a lower price by the collector since farm gate sales cannot take up all the milk produced. Lack of water harvesting capacity in West Arsi leaves the farmer even more vulnerable to water shortages. Dependence on one processor results in farmers being price takers of prices dictated by the processor especially during fasting season when demand is low. Linkages between farmers, chain actors and supporters are very weak and it brings in inefficiencies in the production system and value chain. Farmers having other business reduces the dependence on income from dairy, the different businesses can fund each other when necessary and this improves their resilience.

5.7 Inclusive and resilient business models

The study found two main farming systems models the first is the specialised dairy farming which is mostly found in the urban areas and a crop-dairy integrated system. Within the specialised dairy farming system implementing the climate smart practices identified above is also dependant on making chain linkages with key stakeholders such as feed supplier such that the farmer has access to quality feeds at all times at reasonable price. In this chain linkage, the farmer can have a partnership with the forage supplier such that the dairy farmers give back the manure to the crop farmer and return the dairy farmer get roughages although this can increase in transport costs. In the crop-dairy system, the farmer can have more of a circular approach within the farm such that one waste of a subsystem is an input to the other. This will ensure costs are kept low whilst minimising the negative environmental impact of dairy farming. However, in both systems linkages and partnerships with the right stakeholders and shareholders is key to building sustainable dairy farming system. Farmer is differentiating themselves by offering various value proposition, for example, East Showa 2 farm is differentiating itself by introduced untouched milk through the use of milking machines, the improved hygiene enables them to venture into cheese production (plans underway) and sell milk to the high-end consumers such as hotels and restaurant. East Showa 3 is going for the integrated value chain functions starting from milk production to retailing whilst creating shared value with households surrounding the farm by selling milk to them at lower prices than the market price. In all the study units the triple-bottom-line was not achieved as the main focus is on economic profit and this reduces the sustainability of the dairy farming system. Incorporation of the structures identified in the economic social and environmental canvass models in figure 22-25 can contribute towards the implementation of inclusive and resilient climate smart business models.

5.8 Reflection as a researcher

As a result of failure to secure visa that covers, I had two weeks less to collect all the data and this could have impacted negatively on the quality of my data. To make sure I spent as much time as possible per farm I ended up choosing farms that were close to each other so that I spend less time travelling. This may have resulted in the choice of my research unit not being representative of the actual farming systems in the milkshed. I started splitting the day such that in the morning I observe one farm and in the afternoon I move to the next. The following day I would alternative the farms such as I get to observe both morning and morning activities. Although I managed to collect all the information I needed I felt if I had more time I would have covered farms that are not close to each other and also spent more time per farm such that I don't miss any important information. With the help of my translator I managed to continue getting more information after I had left. He also carried out the focus group discussion on my behalf although this may have compromised the quality of my data. What I learnt is planning ahead and making sure I understand more about the study area especially if its foreign country you will be visiting is very important. I intend to make sure that this does not happen again by paying more attention when I am planning.

The research set out to make the linkage with feed supply and this included finding specialised fodder farm. I tried my very best to find the fodder farm but couldn't and it was very disappointing by visiting an institution hoping they can help locate these farms. I tried getting help from Rif valley university,Oromia state university, the livestock agency and ILRI staff from the AGP2 program that was in the area. Unfortunately, I did not manage to find the farm and I had to replace it with a dairy farm with fodder production. It made me feel like I did not achieve all that I intended to in my fieldwork. Tracking the feed production was difficult since the crop residues were sold at a spot market and the crop residues would have passed through many hands so assessing the crop production system was not possible. I had to include an interview with the crop expert in the area in order to get insights on the crop production system and this reduced the reliability of the information as it gave a general picture instead of specific information. I realise things don't always go as planned and having backup plans always helps in making sure the data is collected despite the changes. I should have planned my fieldwork better by making the connection with key organisations that may have the information instead of leaving everything to the time I arrive in the area of research. I would make sure this does not happen again by making the necessary plans beforehand.

I discovered that farmers didn't keep any records so I had to use their word of mouth together with observations. The total feed per animal was given by the farmers were too high especially on a straw diet, it was quite confusing only to discover during my observation that it was an error in terminology. What the farmer called a quintal scientifically its 100kgs yet their quintal was about 20kgs. The strange thing was I had a livestock expert, a development agent and a junior researcher from Adami Tulu research centre and they were calling that bag a quintal too. Another term that was wrongly used was the compost, it left me wondering the quality of knowledge and expertise they are imparting onto the farmers if they hadn't picked up on the error. I learnt that the use of as many data collection tools during fieldwork improves the reliability of findings through triangulation. I started making sure I use all the tools as much as possible including additional interviews and informal interaction with farmers' wife to get as much information as I can. In the future, I would like to pay more attention when coming up with a methodology that is comprehensive such that I use as many tools as possible to improve the reliability of my data.

Whilst interviewing different individual within the farm I realised the difference in the information given by the farmers and the farmhands. Although what the farmer said sounded technically correct but observing the farmhand distribute the feed I realised what the farmhand had said was what was happening on the ground. As a result, I made a decision to use information that concurred with what I had observed. Group feeding was common in most of the farm, as a result, I used the cow dry matter intake as a starting point then bulls, heifers and calves were allocated 1.2; 0.8 and 0.3 of what the cow was consuming as a way of estimating actual feed intake per animals so that it matches my observations. This may reduce the reliability of the information I collected. I learnt next time I need to take with me basis measuring tools so as to improve the accuracy of the information I collect.i also did manage to verify

if the feed intakes given my the farmer matched the milk output and this reduces the validity and reliability of my findings.improving my time management so that I have time to do all the analysis is my plan towards improving my analysis.
I had limited involvement in contacting and organizing the meetings with the farmer since they did not speak English, as a result, my translator handled it on my behalf. My translator is a senior researcher at Adami Tulu research centre who also worked with the last year students so he is very familiar with the project. He also pre-selected the farms based on my specifications. He showed so much interest and knowledge in the research, he managed to carry out the focus group discussion and in the process business triple base canvas models were developed and verification of data. He also managed to communicate the findings to the farmers. I realised that as much as I prefer doing everything myself delegating is also ok. I realise accepting help is also good in instances where I cannot do it myself. I think this is an area I need to work on more so that I learn to let go of things that are beyond my control and let others help me. With the lessons I have been getting I know I will get it right.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a summary of results from the study in answering the research questions and the objective of the study.

6.1 Environmental and economic costs in dairy farming businesses

It was observed in this study that economic cost are the feeds constituting at least 60% however, feed is also a weak link in the milk characterized by seasonality of feed supply and price fluctuations making the feed expensive as confirmed by Bradsma et al. (2013) and Van Geel et al. (2018). In as much as the feed is expensive, it plays a central role in determining economic costs and benefits in all the cases studies. As a result, feed is both environmental and economic cost. Even with supplementary concentrates digestibility is still low and this increases volatile solids excreted, IPCC (2006) confirms that low digestibility in feeds leads to higher VSE, therefore, more manure produced causing environmental cost. The carbon footprint observed in this study shows a marked improvement towards a reduction in GHG emissions although more can still be done to reduce both environmental and economic costs.

The lack of reliable AI service is a contribution to the cow lifetime productivity of an animal through a long calving interval. And this is very important in reducing GHG emissions and reducing cost. The studied farms have 97.8% in West Arsi and 97.2% in East Showa is the Holstein-Frisian breeds showing how much the farmer has invested in exotic breed through production varies greatly and this can be a management issue considering the breed is the same. The milk yield per cow is high unfortunately the long calving interval and late age at first calving reduce the overall milk produced by a cow in its lifetime. This directly increases GHG emissions. As farms strive to increase economic profitability focus is placed on economic profit but less on the environmental cost which is still very high. By managing environmental cost as observed in this study through improved productivity per cow economic gains will be realised. The total environmental cost of milk is a carbon footprint of 1.42-4.57 kg CO_2 which is still very high although when compared to Tespfahun (2018) the farmer is more climate smart than those in the previous study.

Use of solid storage instead of composting or anaerobic digester was both an economic and environmental cost as a result of GHG emissions as shown in the anaerobic and composting scenario 4 in section 4.4 that reduced the emissions from manure management also confirmed by IPCC (2006). Use of the anaerobic digester and composting have a significant impact in reducing GHG emissions as a result of their ability to reduce CH_4 and N_2O that have very high global warming potential as confirmed by UNFCCC (2019). The high cost of investing in anaerobic biogas digester could be the reason for the low adoption of the practice. However, for farmers that have high electricity bills investing in biogas powered machinery can make the investment worthwhile. Other environmental cost includes eutrophication of water bodies as a result of leaching and runoff of nutrients in the manure (Steinfeld, 2006) as a result of the storage of the manure in the solid storage. In dairy farming systems separating economic and environmental cost is very difficult as they are interconnected with high GHG emissions associated with lower gross margins.

6.2 Scalable climate smart practices

Table 37 summarises the climate smart practice that can be implemented, the benefits that will be obtained and the persons responsible.

Table 39: Climate smart practices recommended

Advised Practice	Objective	Constraint addressed	Benefits	Responsible person
Exotic crossbreeds	-Improve production and reproductive traits	-Low productivity by indigenous breeds	1752-4238 litres per cow per lactation year	-Farmer -Government
AI with efficient and reliable service	-Increase farmer access to breeds with high milk yield potential	-Low milk yield by indigenous breeds	Increase in gross margin of 69234-326848 per year	-Farmer -Extension service -Livestock agency -Private AI technicians
*Fodder production that includes legume plants	-Improve access to forage with high digestibility	-Dependence on crop residues with low digestibility	Creation of carbon sinks	-Dairy farmer -Specialized fodder farmers
Straw treatment	-Improve the digestibility of crop residues	-Low digestibility in crop residues	-11-47% increase in gross margins -3-49% reduction in emissions	-Farmer -Farmer research group -Adami Tulu research centre
Replace low yielding cows	-Maximize milk yield per animal	-Reduce overall farm GHG emissions		-Farmer
Replace male animals with females	-Specialize in keeping milk yielding animals	-Reduce overall farm GHG emissions	-156816-689700etb earned per year -26-38% reduction in GHG emissions	-Farmer
Herd health management	-Increase cow productivity	-Long calving interval -Low weaning weights -Long age at first calving -Calf mortality	Contributes towards high increased productivity	-Farmer -Development agents -Adami Tulu research centre -Livestock agency
Mineral supplementation	-Prevent mineral deficiency	-Mineral deficiency	Contributes towards high increased productivity	-Farmer
Supplementation with high energy and protein concentrates	-Improve the quality and digestibility of the ration	-Low quantity and quality of forage especially crop residues	1.23-3.49 kg CO_2 eq per litre of milk	-Farmer

Disease control	-Control diseases that affect both physical and financial performance of cows	-High mortality and morbidity and losses from diseases such as mastitis	Contributes towards high milk yield	-Farmer -Livestock agency -Development agents
Manure management using composting	-Return the nutrients back to the soil through the use of manure as a fertiliser	-Low soil fertility -nutrient overload in urban areas	51-90% return on investment -minus 15 and 7% GHG emissions	-Dairy farmers -Crop farmer
Separation of urine and dung	-Reduce GHG emissions	-High GHG emissions when manure and urine are combined	75% reduction in ammonia formation	-Dairy farmer
Anaerobic digester	-Reduce CH_4 and N_2O emissions whilst generating green energy	-High CH_4 and N_20 emissions from manure -shortage of electricity in Ethiopia	-minus 5-60% increase in gross margin - minus 25 and minus 40% reduction in GHG emissions	-Dairy farmer Interested community members and institutions
Correct application and timing of manure	-Reduce volatilistaion of nitrogen	-Loss of fertility in croplands	Reduced leaching and volaitiliastion	-Dairy farmers -Crop farmers -Extensionist
Minimum use of machinery and the use of efficient machinery	-Reduce emissions from fossil fuel consumption	-GHG emissions from fossil fuel consumption	0.03-0.13kg CO_2 eq/litre of milk	-Farmer -Machinery service providers
Staff training and capacity building and record-keeping	-A clear understanding of animal handling	-Improper handling of animals affecting the cow environment	Contributes towards high milk yield	-Farmer -Farmhands
Water harvesting	-Adlib access to potable water times	-Reduce water shortages	Contributes towards high increased productivity	-Farmer
Improved hygiene practices	-Improve hygiene and reduce disease outbreaks	-Poor hygiene practices		-Farmer -Farmhands

GHG emission from fodder production was not calculated.

6.3 Scalable business models

This section focusses on making recommendations to the commissioner and other stakeholders on scalable climate smart practices that can be implemented and what can be used to improve the resilience and inclusiveness in the dairy business systems. The use of the triple base canvas is meant to capture the sustainability aspect of the dairy farm. As shown in the triple base canvas business model in figure 22-24 a lot of attention is given in creating shared value over capturing the economic value and that is the basis for sustainability in the recommendations from this study

6.4 Recommendation

Recommendations to the commissioner

It has been observed in this study that milk yield per cow is quite good, however, the long calving interval and long age at first calving it reduces the lifetime productivity of the cows and increases the GHG emissions. As was also established high GHG emissions directly reduce the profitability of the dairy farm and this makes feed a critical area if productivity per animal is to be achieved. Based on climate smart practices given in table 38, their impacts and benefits the commissioner is advised on the cost and benefit of each climate smart practice and this can be used to scale up and scale out climate smart practices in inclusive and resilient dairy farms. The commissioner together with key stakeholders identified during fieldwork is advised on vertical and horizontal linkages that need to be made in order to give farmers access to inputs and services necessary in their businesses. Choice of climate smart practices should be done from a systems perspective and specific for each farm because some climate smart practices do not always have the same impact under different circumstances. Use of feedback given in the triple base canvas can enable farmers to achieve sustainable business models that create shared value, capture value and fair value share distribution in the chain.To build the capacity of the farmers the commissioner is advised to address the weak linkages in the dairy farming system by linking and capacity building of dairy value chain actors and support service on how to improve:

Feed

- Feed quality, supply, and ration formulation
- Promote fodder production projects especially include leguminous plants
- Mineral and concentrate supplementation

Manure management

- Promote composting and anaerobic digesters

Access to quality information and training

- Farmer training on animal husbandry, farm management, and record-keeping
- Increase awareness on climate smart practice suitable for that specific farm in order to maximize the returns at the same time reducing environmental costs.
- Promote vertical and horizontal linkages that support implementation, scaling up and scaling out of climate smart practices
- Promote training of trainers so that diffusion of climate smart practices is faster

Herd management

- The efficiency of AI service and availability
- Productivity per cow-age at first calving, calving interval and lactation length
- Herd health management

Adami Tulu research centre

- Offer farmer consultancy service since extension service is limited on climate smart practice in table 38, disease control, animal health management waste management, and record-keeping
- Work with the farmer research group in making sure farmers have up to date information and training and innovation such as straw treatment
- Offer refresher training courses to farmers and all key stakeholder in the dairy value chain
- Together with the livestock agency initiate quality standards on concentrates and farm hygiene

Livestock agency

- Improve efficiency on AI service delivery
- Open AI service to a private organisation that is interested
- Set the rules and regulation where antibiotic usage is concerned
- Offer opportunities for youth and women to venture into the dairy business, to access land for fodder production
- Set quality standards, grades, and prices for concentrates and the rest of inputs and minimum hygiene standards for dairy farms and the rest of the processes in the chain
- Promote opportunities for fodder production and preservation especially by the youth
- Create linkages for farmers with stakeholder that offer innovations such as straw treatment, silage making biogas and milking machines

Farmer research group

- Encourage information and innovation sharing platform through peer to peer learning process
- Promote youth and women taking parts in all stages in the dairy value chain
- Farmer training and peer to peer learning
- Create awareness on the link between GHG emissions and farm profitability as an evidence-based measure to motivate farmer to adopt and scale up climate smart practices.

Farmer

- Improve farm husbandry, record keeping, and animal productivity
- In-house training of staff and refresher courses
- Join farmer research group to increase access to information and innovation
- Improve protective clothing for staff
- Provide cows with adlib supply of water

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ANNEX 1

Interview checklist for the feed agent

- Which feeds do you sell?
- Where do you source the feeds?
- What type of vehicles are used during transportation of feeds?
- What is the mode of transport used by your consumers (farmers)?
- What are the prices for all the feed you sell?

Interview checklist for the crop expert?

- Which fertilisers are commonly used in the region?
- What are the fertiliser application rates per hectare in the region?
- What is the manure application rate per hectare in the region?
- What are the main crops grown in the area?
- What type of machinery is used during feed production (ploughing and harvesting)?
- How many how does each equipment take per hectare?
- What is the fuel consumption per equipment?

Interview checklist with an animal health expert?

- What are the common diseases in dairy farms?
- What is the calf mortality?
- What are the main structures in animal health and disease control?
- How is antibiotic access by farmers considering they seem to have unlimited access to prescription drugs?
- What form of education do they give to farmers on antibiotic usage and storage?
- Which platforms do they use in accessing and educating farmers on animal health and disease control?

ANNEX 2: Impacts of livestock on climate change

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 on 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_2$0 from applied and deposited manure							
$N_2$0 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 produced							
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							
The 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	Trasport to the 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								