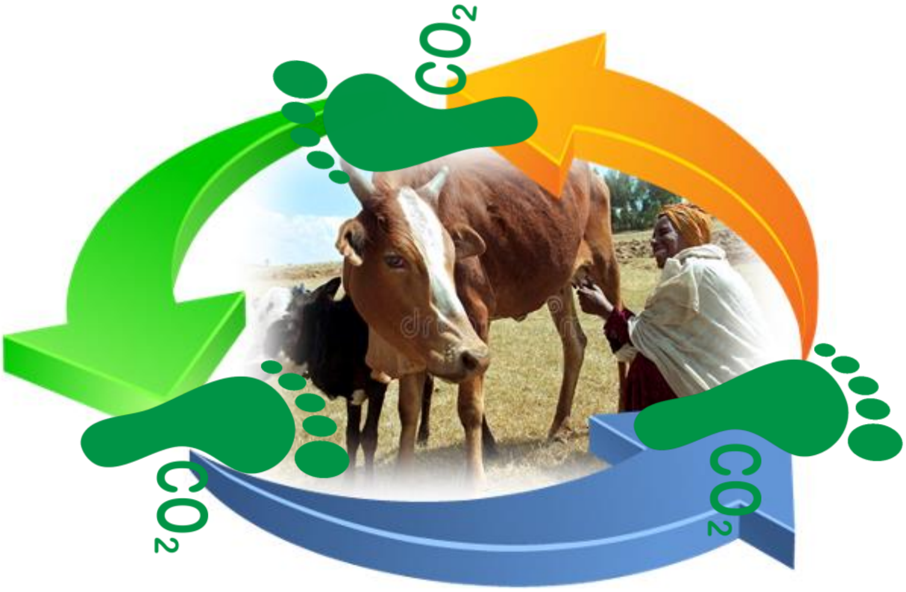
Carbon Footprint of Milk at Smallholder Dairy Production in Zeway – Hawassa Milk Shed, Ethiopia



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September 2018
VHL, Velp
The Netherlands

Carbon Footprint of Milk at Smallholder Dairy Production in Zeway – Hawassa Milk Shed, Ethiopia

Research Project submitted to Van Hall Larenstein University of Applied Sciences in partial fulfilment of the requirements for applied research design module in Agricultural Production Chain Management specialization in Livestock Production Chains

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This research has been carried out as part of the project "Climate Smart Dairy in Ethiopia and Kenya" of the professorships "Dairy value chain" and "Sustainable Agribusiness in Metropolitan Areas".

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Dedication

This master thesis is dedicated to my beloved wife, Mekdes Shambel Alemu

Acknowledgements

First, I would like to pass my deepest gratitude to an almighty God with his mother, St. Virgin Marry for their invaluable support in every corner of my life. Netherlands Fellowship Programmed (NFP) is thanked for funding this international master programme. My heartfelt thank also goes to my research supervisor, Marco Verschuur for his incredible effort throughout the whole research process. Vries Jerke de (PhD) is appreciated for is unreserved support and constructive feedback during the research process. In connection, the host education institute, VHL University of Applied sciences receives my appreciation in acquainting me with relevant and standard knowledge and skills in the program. My sincere thank also goes to CCAFS project in sharing costs of this research. I would like to thank Mr Shimelis Getachew from Adami Tulu Research Center for his facilitation in the field work. Finally, I would like to extend my heartfelt thanks to smallholder dairy farmers for their cooperation and reliable information.

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Abstract

This study was conducted in Ziway - Hawassa milk shade, found in Oromia administrative region, Ethiopia with the objective to design suitable business models through quantifying greenhouse gas (GHG) emissions from smallholder milk producers. Five districts (Shashemane, Arsi - Negelle, Kofelle, Adami Tulu and Dugda) were selected from West Arsi zone and East Shewa zone by their milk production and supply in the shed. Field data were collected from eighty urban and peri-urban smallholder dairy farmers from all districts through a structured questionnaire. Focus group discussion with farmers was conducted, and participatory tools were applied (business model CANVAS, gender task division chart, rainfall distribution and crop and residue production calendar). Questionnaire data was coded and filled in to excel spreadsheet. Statistical Package for Social Science (SPSS) software was used to analyse data. Descriptive statistics (mean, minimum, maximum) was applied to summarise and present data in graph, table and chart to compare with different producer groups. Lifecycle Analysis (LCA) approach was used to quantify GHG emissions from smallholder dairy production. Emission factors and GHG emission estimation equations from different sources were applied from Intergovernmental Panel on Climate Change (IPCC).

Majority of Urban dairy farmers (72 .5%) practised only livestock farming, and their major intention was milk production. However, peri-urban dairy farmers were crop-livestock mixed farmers; they gave equal emphasis to crop and milk production. Smallholder dairy farmers in the shed kept dairy cattle for multifunction (milk, meat, draught, manure, finance and insurance) of which milk production was the primary. An Urban dairy farm produced significantly higher milk per day (12l) as well as per year (9260 l) than peri-urban dairy farm (6.5 L/day and 5500 L/year). The major feeds identified for dairy cattle were crop residues, industrial byproducts and local distillery byproduct. Feed scarcity was severe during the rainy season (February, March, July and August) when farmers cultivate crops. The majority (80% in urban and 76% in peri-urban) of farmers were not aware of greenhouse gas emissions from dairy cattle management. In peri-urban, females contributed higher labour in processing milk at home (72%), manure collection from barn (62%) and milk selling (65%) while attending of cows and selection for breeding was the main (79%) duty of male farmers. Majority of dairy farmers in the milk shade either utilize manure as fertilizer and fuel or sale manure. In addition, the majority of farmers in the shed managed manure as a solid storage system (62% in urban and 51% in peri-urban) and burned for fuel. A Peri-urban dairy farm emitted higher (255 $KgCO_2eq$/year) greenhouse gases than urban dairy farm (179 $KgCO_2eq$/year) from crop residue production. However, an urban dairy farm emitted higher (4748 $KgCO_2eq$/year) greenhouse gas than peri-urban (2203 $KgCO_2eq$/year) from off-farm feed production. There was no significant difference in average emission from feed transportation between urban (27 $KgCO_2eq$/year) and peri-urban farm (31 $KgCO_2eq$/year). An average peri-urban dairy farm emitted significantly higher enteric CH_4 (23206 $KgCO_2eq$/year) and N_2O (64 $KgCO_2eq$/year) from manure management. Overall, the carbon footprint of milk production under the smallholder dairy system in urban and peri-urban was 2.07 $kgCO_2$ eq/ litre and 4.71 $kgCO_2eq$/ litre. This was reduced to 1.76 $kgCO_2eq$/ litre and 3.33 kg CO_2eq/ litre for milk production when multifunction of dairy cattle was considered. peri-urban dairy farms emitted higher greenhouse gases when producing or providing different functions per unit. In general, the study indicated that enteric CH_4 had a huge contribution (80%) in the carbon footprint of smallholder dairy farm. Improvement in cow genetic makeup and feeding system were ideal decision to reduce carbon footprint in the current milk shade.

Keywords: Multifunction, urban and peri-urban, Smallholders, carbon footprint.

CHAPTER ONE: INTRODUCTION

1.1. Background

Climate change is taken as the main threat to the survival of different species, ecosystems and the livestock production sustainability in many parts of the world. GHG (Greenhouse gases) are released into the atmosphere both by natural sources and anthropogenic (human-related) activities (Sejian and Naqvi, 2012). Developing countries are more susceptible to the effects of climate change due to their high reliance on natural resources, insufficient capacity to adapt institutionally and financially and high poverty levels (Thornton et al., 2009). Greenhouse gas (GHG) emissions have gained international attention due to their effect on global climate. There are many sources of GHG emissions, with agriculture estimated to contribute about 11% of all global emissions (Smith et al., 2014), of which the livestock sector contributes 14.5% of global greenhouse gas emissions, driving further climate change (Rojas-Downing et al., 2017).

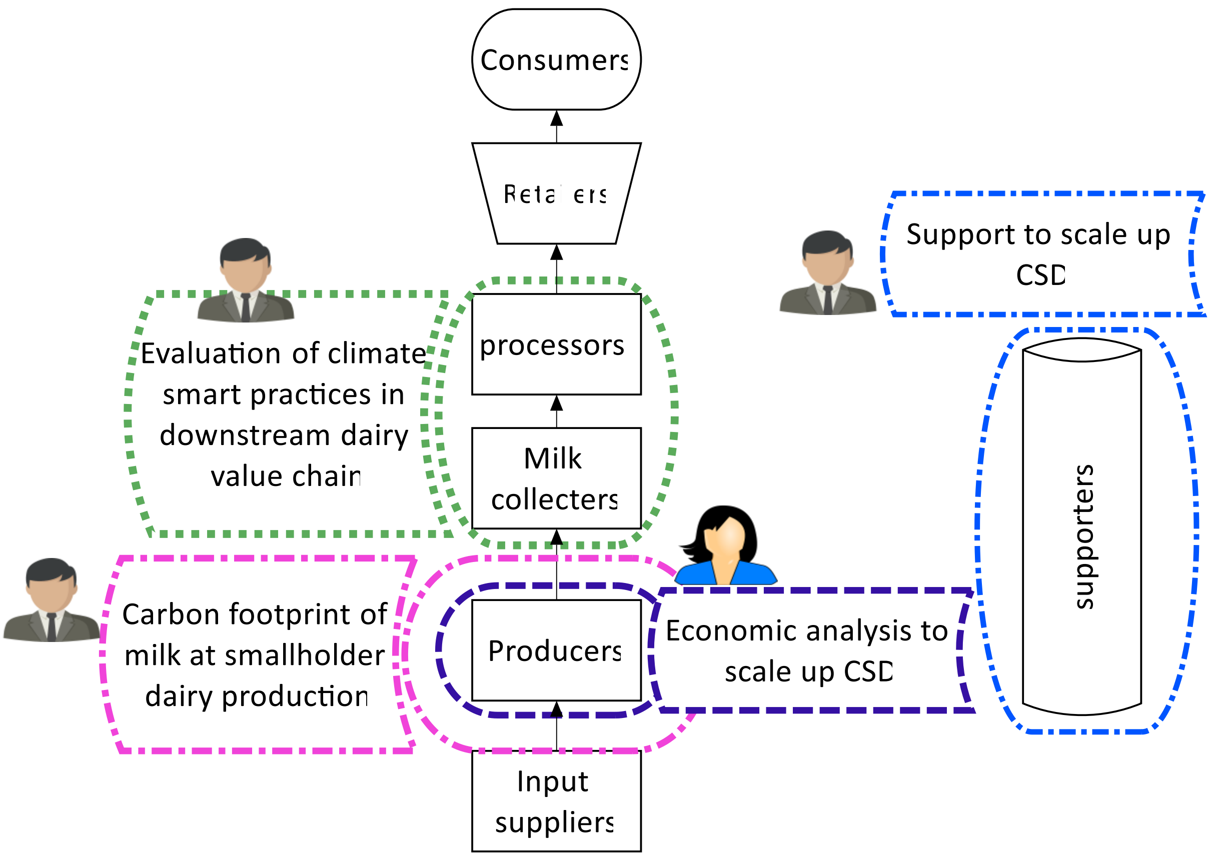
Dairy farms are an important source of greenhouse gas emissions. The primary GHG emissions in dairy farm include methane (CH_4) from the animals(enteric) and manure, Methane(CH_4) and Nitrous oxide(N_2O) from manure storage and during field application. Also, Nitrous oxide is released from nitrification and denitrification processes in the soil used to produce feed crops and pasture (Rotz 2018). In Ethiopia, milk production is majorly from smallholder production from indigenous breeds, which are kept for multipurpose function in different agro-ecological zones (Yigrem, 2015). According to the report by FAO (2017), there are 14 million estimated households of livestock keepers, of which 63% keeps less than three tropical livestock unit. The sector is an enormous contributor for climate change through emission of greenhouse gases, generating 65 million tons CO_2 (40% of emissions in 2010) equivalent GHG, and is predicted to contribute 124 million tons in 2030 (FDRE, 2011). Climate change is an essential concern to Ethiopia in time and needs to be tackled in a state of emergency (Zerga and Gebeyehu, 2016).

In Ethiopia three main dairy production systems are identified; i.e. urban system, peri-urban system and rural systems. Smallholders keep cattle for multipurpose; produce milk for the market, home consumption, manure and draught power, Insurance, and security for future financial needs. (Behnke and Metaferio, 2011). From the major eight milk sheds, the Zeway- Hawassa is the one found in the west- south of the country majorly in the rift valley of Oromia region. According to IPMS report, more than 97% of the urban producers in the town of Shashemane use their own residence compound for dairying. The majority of producers (61.7%) in the mixed crop-livestock system process milk at home, while the majority of urban producers (79.2%) produce milk for sale (Yigerem et al., 2008).

1.2. Project description

Van Hall Larenstein University of Applied Sciences got research call from CCAFS (Research Program on Climate Change Agriculture and Food Security) in scaling up climate-smart agriculture. The research aims to describe business models of chain actors and supporters to identify opportunities for scaling up good climate-smart dairy practices in Ethiopia and Kenya. It is linked to "Nationally Appropriate Mitigation Actions" (NAMA) to reduce GHG emissions from dairy production. In this research project master students (agricultural production chain management students of VHL University of Applied Sciences) were involved. Students were grouped into two research teams (Ethiopian and Kenyan) to conduct research in these two countries. Four master students were included in the Ethiopian group focused on climate-smart dairy of the milk chain in Ziway -Hawassa milk shade. The portions of milk value chain were divided among four of us; i.e. carbon footprint of milk on producer level, economic analysis of milk at the producer level, Evaluation of climate-smart practices in the downstream dairy value chain (collection processing) and support to scale up climate-smart dairy. The main aim of these four research topics was to design climate-smart business models for the chain actors and supporters. These four topics finally combined to give the overall picture of milk value chain. I was focused on carbon footprint of milk at smallholder dairy production (Figure 1).

Figure 1. Research topics by the Ethiopian students research team in the dairy value chain



Source: Ethiopian research team sketch

1.3. Problem statement

Supplies fail to meet the demand for milk due to an increase in consumption that resulted from a rise in income and population growth. Although the Livestock Master Plan (LMP) had strategies to enhance livestock production, also lead to a rise in GHG emissions (MOA, 2015). The CRGE of Ethiopia had a strategy to reduce GHG emissions from the livestock sector. Therefore, there is a need to Integrate climate-smart strategies in Livestock master plan. Zeway-Hawassa milk shed is one of the major milk shed in a country dominated by smallholder dairy farmers. GHG emission per unit of production is higher in smallholder dairy farms than commercial farms due to low productivity (De Vries et al., 2016). This is due to limited knowledge in climate smart dairy practices at smallholder dairy production which is central to rising milk production at the same time reducing GHG emission. Van Hall Larenstein University of applied sciences and CCAFS (Research Program on Climate Change Agriculture and Food Security) took the initiative for this study linking with Adami Tulu Research Centre in Ethiopia. Of course, Agriculture and livestock resource office also had a part in implementing climate smart dairy production.

1.4. Research objective

To design suitable business models through quantifying greenhouse gases (GHG) emissions from smallholder milk producers.

1.5. Research questions:

1. What are the dairy farming system and gender involvement at smallholder dairy farming in the milk chain?
    - 1.1. What are the functions and milk production of dairy cattle in smallholder dairy farming?
    - 1.2. What are the feed inputs for smallholder dairy farming in the current milk chain?
    - 1.3. What are the manure utilisation and handling systems?
    - 1.4. What is the role of gender in climate-smart dairying?

2. What is the greenhouse gas emission from smallholder dairy farms?
    - 2.1. What is the carbon footprint of multifunctionality?
    - 2.2. What is the carbon footprint of milk production?

CHAPTER TWO: LITERATURE REVIEW

2. Milk production systems and GHG emission

2.1. Milk production systems in Ethiopia

In Ethiopia three main dairy production systems are identified; i.e. urban system, peri-urban system and rural systems. These systems are defined by its agro-ecology, location, their main production objective, resources and resource use, the scale of production and management, market orientation, and access to inputs and services (Tegegne et al., 2013). It is estimated that 63% of the dairy cattle population is found in the mixed crop-livestock dairy system and about 72% of the total milk production in Ethiopia is produced on these smallholder farms (FAO & NZAGRC, 2017). Urban and peri-urban smallholders are specifically targeting consumer in the nearby town and city and are the main suppliers of raw milk to different scale processors (Haile, 2009 and Land O'Lakes Inc., 2010).

2.1.1. Urban dairy systems

Urban dairy systems are situated in cities and/or towns. This system is used intensive management and producers focuses on fluid milk production and sale with little land resources, using the available human and capital resources mostly for specialised dairy production under stall feeding conditions (Land O'Lakes Inc., 2010). When compared to other systems they have relatively better access to services (e.g. artificial insemination) and inputs (e.g. feeds) provided by the public and private sectors (Tegegne et al., 2013). The urban system consisted of 5167 small, medium and large dairy farms producing about 35 million litres of milk annually. Of the total urban milk production, 73 percent is sold, 10 percent used for household consumption, 9.4 percent goes for feeding calves and 7.6 percent is locally processed at home (Yilma et al., 2011).

2.1.2. Peri-urban dairy system

The peri-urban milk production system includes smallholder and commercial dairy farms in the proximity of city capital of the country and other regional towns. This sector controls most of the country's improved dairy stock (Yilma et al., 2011). The peri-urban dairy system of Shashemane and Hawassa are located at the periphery of these towns that have relatively better access to urban centres where dairy products are highly demanded. The primary production objectives of this system are the sale of fluid milk and some local butter. Besides dairy, cattle are also kept for manure (fuel production and fertilise the soil), and male animals are kept for draught power. Peri-urban dairy production usually practices mixed crop-livestock farming, which produces part of the feed in the form of crop residues and grazing. Access to inputs or services and marketing is mainly through links with processors in urban centers and public sector or collective action by producers (Tegegne et al., 2013).

2.1.3. Rural Dairy production

The rural dairy system is located in rural mid altitude to highland agro-ecological set-up, and has limited access to urban centres where demand of milk is high (Tegegne et al., 2013). The rural dairy smallholder system produces the most significant share of total milk produced in the country (contributing 98%) (Land O'Lakes Inc., 2010). The rural dairy production system is part of the subsistence farming system and includes pastoralists, agro-pastoralists and mixed crop/livestock producers mainly in the highlands.

The system is not market-oriented, and most of the milk produced is retained for home consumption. Eighty-five percent of the milk produced in the rural area is used for household consumption, seven percent is sold, only 0.3 percent is used for wages in kind, and the remaining eight percent is used for the production of edible and cosmetic butter and *Ayib* (Yilma et al., 2011). Similar with peri-urban producers, the rural dairy systems have access to land. The rural dairy systems practice mixed crop-livestock farming, which produces part of the feed in the form of crop residues and grazing. Farmers in the rural areas have limited access to inputs and services (Tegegne et al., 2013).

2.2. Manure management in the milk shed

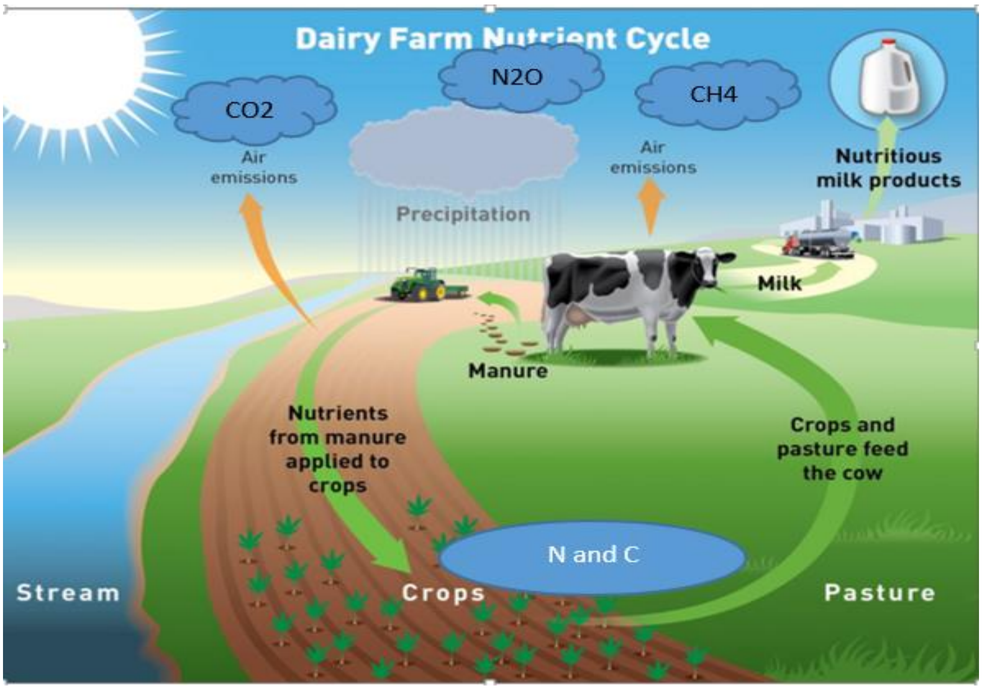
In some areas in the rural highland dairy production system, dairy animals are tethered around farm lands or communal grazing area to fertilise the land. In rural highland dairy system manure is also used as a source of fuel. In the peri-urban dairy production system of Shashemane–Hawassa milk shed, manure is used to fertilise croplands particularly in the enset–coffee-based farming system (Tegegne et al., 2013). Paradoxically, 47% of urban dairy farmers in the same milk shed extra money to dispose cattle manure from their farm, while 34% use manure primarily for fuel. Manure is an essential input for crop production and for nutrient recycling in the rural and peri-urban dairy production systems, but in urban settings, it has limited importance and challenges dairy farming (Nigus et al., 2017 and Tegegne et al., 2013). Using manure as fertiliser can minimise depletion of nutrients and organic matter in soils used for crop production in rural or peri-urban areas, and less accumulation of nutrients in urban areas (De Vries et al., 2016).

2.3. Nutrient cycle in milk production

Nitrogen and carbon flow through the typical dairy production system to provide nutrients to both dairy cows forage crops and. Cattle manure is applied to forage crops that utilise the nitrogen and nitrogen mineralised from the manure for forage growth (The crops are then harvested and fed to dairy cows that, in turn, use the elements for milk production and growth). A portion of Nitrogen is excreted as manure from cows, and the cycle is renewed (Figure 2) (Hellmuth and Hochmuth, 2015). Approximately 30% of the nitrogen eaten by a cow is converted into milk and meat, and also a small portion is lost to the atmosphere as a gas(N_2O). A significant proportion of the nitrogen excreted from the cow will be returned to the soil (into the soil pool) as plant residues or as dung or urine. In the soil pool, nitrogen is converted into forms that are available for plants to uptake. The exact breakdown of where nitrogen goes after it enters a farm system will vary between farms and paddocks (Dairynz, 2013).

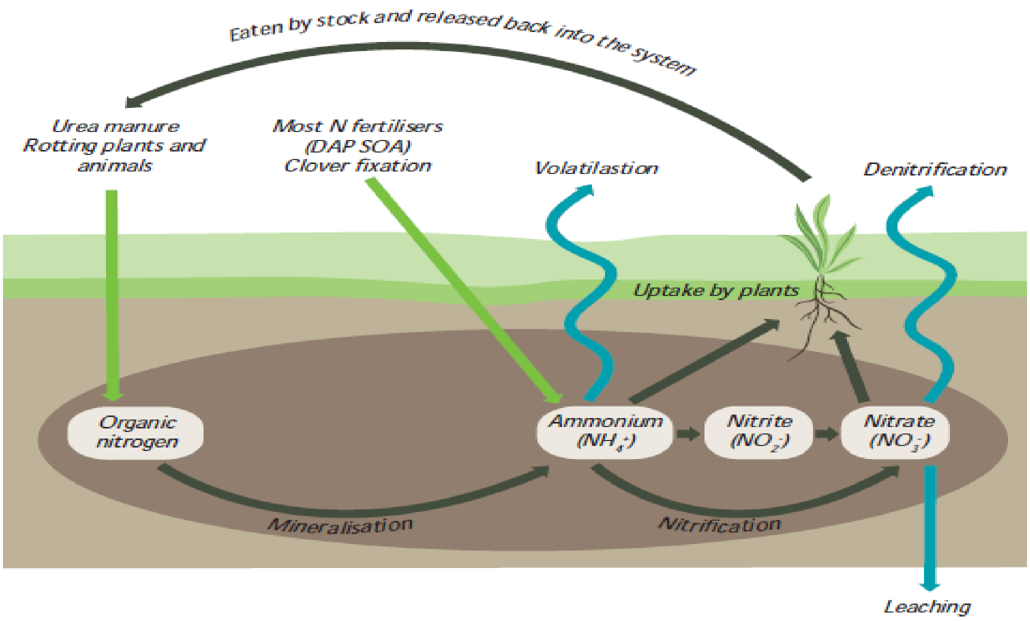
A shown in Figure 3, If soil temperatures are above 50°F, ammonium will start to be converted to more mobile nitrate form by microbes trough nitrification. Leaching can occur when the nitrogen(N) has been converted to nitrate. Nitrate is water soluble and does not attach to the soil, therefore excess nitrate can move below the root zone in certain conditions as water passes through the soil. (Dairynz, 2013 and WYFFELS HYBRIDS, 2013). Denitrification is occurred by bacteria that usually result in the escape of nitrogen into the air in saturated soils and an anaerobic environment. volatilization coccurs commonly from animal manure or urea fertilisers when nitrogen is in the organic form. When this happens, the nitrogen is converted to ammonia gas (NH_3) and lost into the atmosphere (Dairynz, 2013).

Figure 2. Nutrient cycle in the dairy farm



Source: Adapted from Dairynz, 2013

Figure 3. Nitrogen cycle



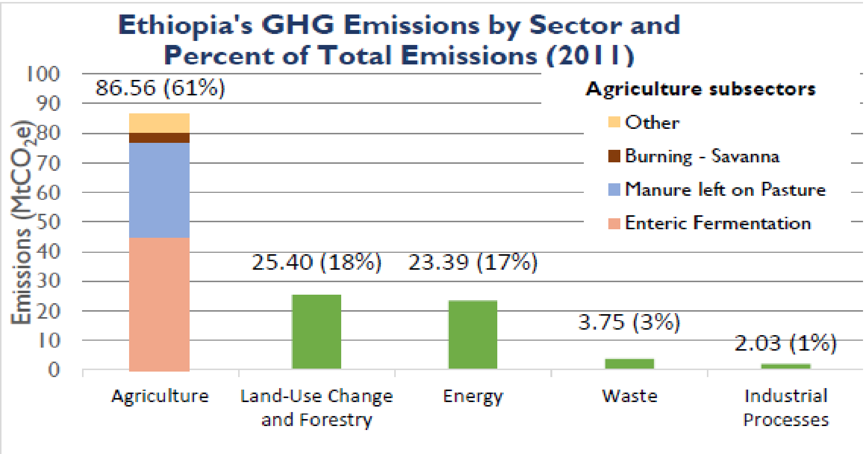
2.4. Climate change

Climate change refers to long-term fluctuations in temperature, precipitation, wind and other elements of Earth's climate system. It is a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global and/or regional atmosphere (Zerga and Gebeyehu, 2016). Greenhouse gas (GHG) emissions have gained international attention due to their effect on global climate, and the consequences of continued warming are likely to be severe (Henderson et al., 2017). There are many sources of GHG emissions, with agriculture estimated to contribute about 11% of all global emissions (Smith et al., 2014).

2.5. GHG emission and Climate Resilient Green Economy in Ethiopia

The profile of Ethiopia's GHG is lead by emissions from the agriculture sector, followed by land-use change and forestry (LUCF), and energy sector emissions. As Figure 4 indicates, the agricultural activities that contribute the most to the sector's emissions are enteric fermentation (52%), manure left on pasture (37%), and burning of the savanna (4%) (USAID, 2015).

Figure 4. Ethiopia's GHG emissions by sector



Source: USAID, 2015

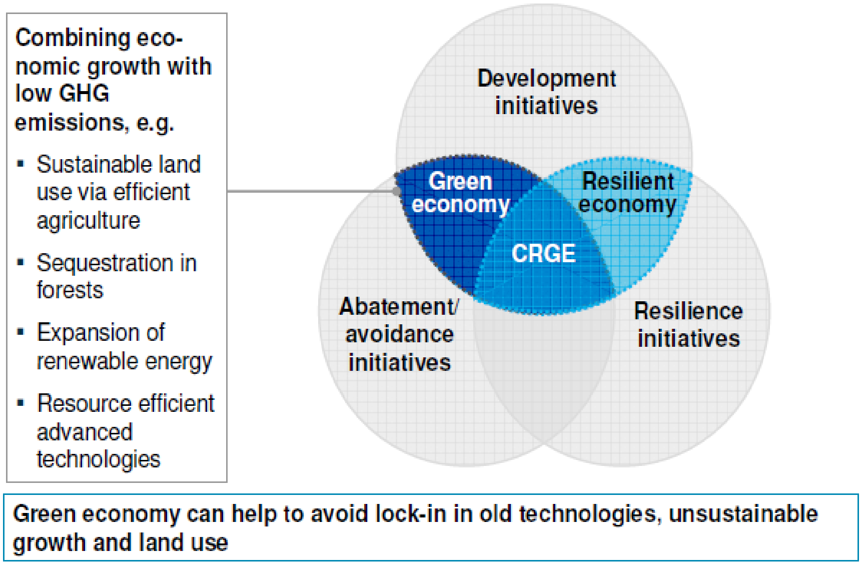
In 2025 Ethiopia plans to achieve middle-income through green economy development path. It is realised that the conventional development path would increase emission of GHG and unsustainable utilisation of natural resources. The government of Ethiopia has developed a strategy to build a green economy to minimise such adverse effects (FDRE, 2011).

The Climate-Resilient Green Economy (CRGE) initiative identified and prioritised more than 60 initiatives. These initiatives could help the country achieve its development goals while limiting 2030 GHG emissions to around today's 150 Mt CO_2e – about 250 Mt CO_2e less than estimated through a conventional development path. The green economy identified the following four pillar.

1. Improving livestock and crop production and reduce emissions
2. Protection and re-establishing forests for economic and ecosystem services(carbon stocks)
3. Generation of electricity from renewable sources
4. Advancing modern and energy-efficient technologies in transport, industrial sectors and buildings.

Implementing these pillars revert the economy from being locked into an unsustainable pathway and can help to attract the investment required for their development (Figure 5).

Figure 5. Climate-resilient green economy of Ethiopia



Source: FDRE 2011

2.6. Contribution of livestock to climate change

Important sources of GHG emissions from dairy farms include CH_4 and N_2O from enteric fermentation, manure storage and handling, and crop and pasture land (Rotz, 2018). Livestock contributes 14.5% of the total annual anthropogenic GHG emissions globally (Gerber et al., 2013). Globally livestock contributes 44% of anthropogenic CH_4, 53% of anthropogenic N_2O and 5% of anthropogenic CO_2 emissions. Livestock influence climate through land use change, feed production, animal production, manure, and processing and transport. The livestock sector is often associated with adverse environmental impacts such as land degradation, air and water pollution, and biodiversity destruction (Bellarby et al., 2013).

In Ethiopia mixed crop-livestock system and the agro-pastoral/pastoral systems are responsible for the bulk of the emissions; 56% and 43% of the total GHG emissions associated with the production of milk, respectively. The small-scale and medium-scale commercial production systems make small contributions to the total GHG emissions, 1.1% and 0.2%, respectively. The emission intensity of milk in Ethiopia is on average 24.5 Kg CO_2 eq./ kg FPCM. Emission intensity were on average 44.6, 18.9, 8.7 and 3.8 kg CO_2 eq./ kg FPCM for mixed crop-livestock, pastoral and agro-pastoral, small-scale commercial; and medium-scale commercial systems, respectively (FAO & NZAGRC, 2017).

2.6.1. Enteric emission

Enteric emissions are the largest source of GHG on a dairy farm. On well-managed confinement farms, they contribute about 45% of the total GHG emission of the full farm system, and on more-extensive grazing farms, the proportion may be a little higher (Rotz and Thoma, 2017). In 2013, the dairy cattle sector in Ethiopia emitted 116.3 million tonnes carbon dioxide equivalent (CO_2 eq.). Within this, enteric methane represents about 87% of the total GHG emissions from dairy production, equivalent to 101.2 million tonnes CO_2 eq. (FAO & NZAGRC, 2017). As microbes ferment the feed in the rumen, they grow and generate volatile fatty acids (propionic acid, acetic acid, and butyric acid) and methane through a series of complex metabolic pathways. Overall, a high-producing cow consuming and fermenting a large amount of feed can emit as much as 500 g of methane per day (Aguerre et al., 2011). Approximately 95% of enteric methane is released through the nose and mouth, and 5% is released through flatulence. Changes in metabolic pathways, types of microorganisms and their growth rate, feed type and amount of feed the animal eats are among the factors affecting enteric methane emissions. Cows with higher feed efficiency (ability to convert feed to milk) might have lower methane emissions (Belflower et al., 2012).

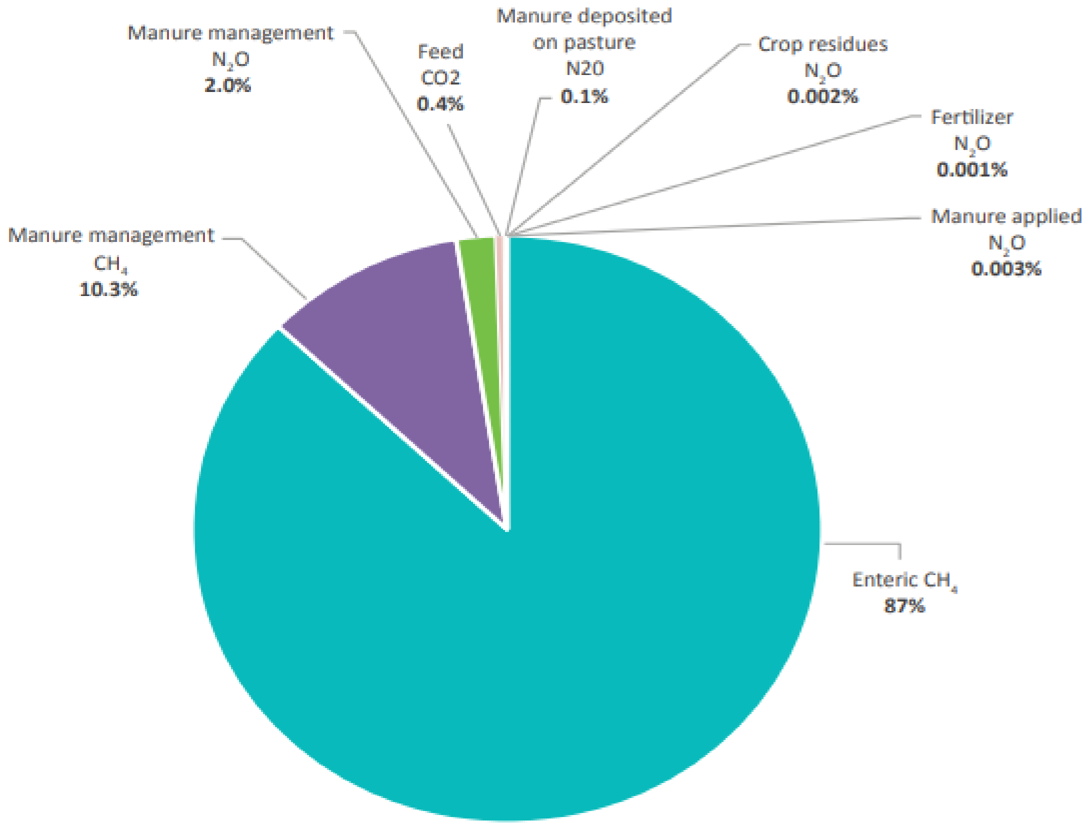
2.6.2. Manure handling and application

Important emissions in manure management include CH_4 and N_2O from manure in housing facilities during long-term storage and during field application. Nitrification and denitrification processes in the soil release N2O during feed crops and pasture production (Rotz, 2018). Globally, cattle are estimated to generate 5,335 Mt of CO_2 equivalents (CO_2e) per year, which is about 11% of all human-induced GHG emissions (Smith et al., 2014). Dairy farms are the main contributor to the total GHG emissions over the life cycle of milk and other dairy products (Rotz, 2018). Within the farm, Emissions associated with the management of stored manure (CH_4 and N_2O) contribute an additional 14.4 million tonnes CO_2 eq., 12.3% of the total GHG emissions from the dairy cattle sector (FAO & NZAGRC, 2017).

2.6.3. Animal Feed production and transportation

In most cases feeds for dairy cattle in Ethiopia are either not available in sufficient quantities due to fluctuating climatic conditions or even when available are of poor nutritional quality. In Peri-urban and rural dairy production systems, cattle ration is mostly composed of low-quality feed products such as crop residues (between 30-35 percent of the ration). Consequently, the digestibility of average feed ration is very low. These constraints explain the low milk yields and short lactations, high mortality of young stock, longer parturition intervals, low animal weights and high enteric methane emissions per unit of metabolizable energy (FAO & NZAGRC, 2017). In general in animal feed production and transportation, sources of GHG emissions include the application of manure and chemical fertilisers to crops, accounting for both direct and indirect emissions (N_2O). Deposition of manure on pasture crops, accounting for both direct and indirect emissions (N_2O) and feed transportation from the production site to the feeding site (FAO,2010). Figure 6 depicts the proportion of different emission sources and GHG emissions in the dairy farming in general.

Figure 6. Emission sources and associated GHGs in dairy farming



Source: FAO & NZAGRC, 2017

2.7. Climate-smart Dairy

Climate Smart Agriculture (CSA) works to establish a 'triple win' scenario in which innovative practices produce better yields, build resilience to climate change (reducing long-term risks) and lower carbon emissions (FAO, 2013). Climate-smart Dairy (CSD) practices help the world dairy in keeping aim to meet our future food requirements without further increase in emissions.

Wide ranges of measures are required to reduce the livestock sectors' climate-change footprint. These include improving production and feed systems, developing new breeds of ruminants that produce less methane, introducing methods of manure management that reduce emissions and integrating livestock with crops to minimise waste and improve soil fertility. Better grazing management could also help to enhance animal nutrition and reduce GHG emissions. There is also a need to consider changing feeding regimes and improving pasture management (Paul et al., 2016).

Climate-smart dairy farming is most important to fight against adverse impacts of changing the climate. All the climate-smart dairy farming practices are not suitable for every region as it mostly depends on various contexts including a particular location. However, climate-smart dairy farming needs to be put into practice with paid attention so that in this changing climate scenario, smallholder farming can sustain with sufficient food security (Paul et al., 2016).

The three interlinked pillars necessary to achieve CSA goal, i.e. food security and development are productivity, adaptation and mitigation (Van Eck et al., 2017).

• **Productivity:** CSA aims to sustainably raise agricultural productivity and incomes without causing an adverse impact on the environment. It is sustainable intensification to increase food and nutritional security.
• **Adaptation:** CSA is also strengthening agricultural farming system resilience, enhancing the capacity of farming to adapt and prosper during shocks and prolonged stresses. Particular emphasis is given to protecting the ecosystem services which are essential for maintaining productivity and our ability to adapt to climate changes.
• **Mitigation:** Wherever and whenever possible, CSA should help to reduce and/or remove greenhouse gas (GHG) emissions. This implies that we reduce emissions for each calorie or kilo of food, fire and fuel that we produce.

2.8. Gender inclusive Climate Smart Agriculture

Climate-smart agriculture strategies are unlikely to be effective, let alone equitable or transformative, without active attention to gender (Bernier et al., 2015). Gender affects adoption of climate-smart agricultural practices (Kumar, 2016). More female and male farmers adopt climate-smart practices in agriculture when women's knowledge, awareness, and access to information about such practices increase. Gender involvement in CSA results in the strength of households resilience, communities, and food systems exposed to climate-related shocks and climate change (WBG, FAO and IFAD, 2015). Gender-based context and constraints must be addressed to increase agricultural productivity, improve food and nutrition security, also to make farming climate resilient (Kumar, 2016).

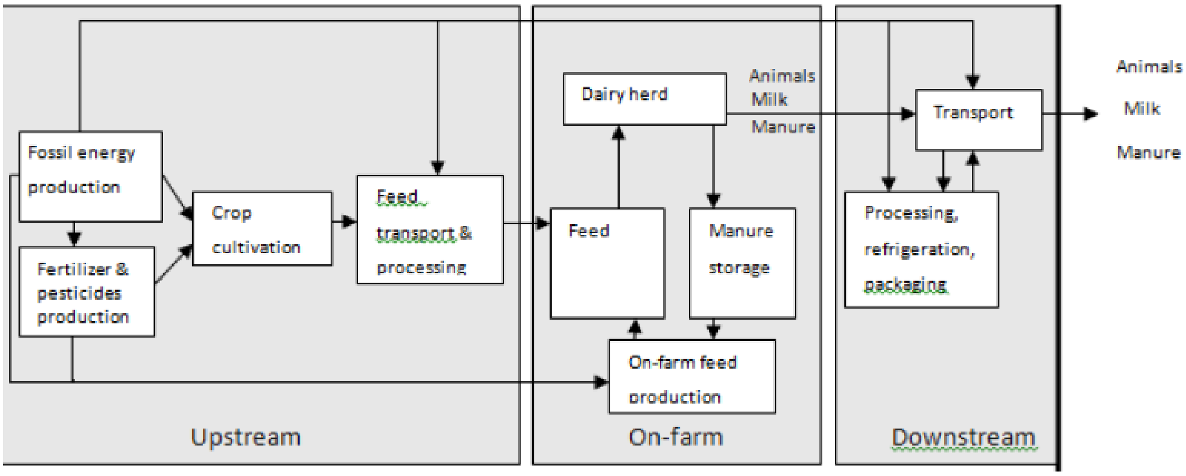
2.9. Life cycle analysis (LCA)

LCA can be used to assess environmental influences of a product under consideration of the production impacts of various processes connected to the product along the whole production chain (Weiler, 2013). LCA can be performed in two ways: consequential or attributional (De Vries et al.,2016). The attributional LCA commonly uses allocation as a means to deal with multifunctional processes or systems while Consequential LCA uses a system expansion approach to deal with multifunctional processes to expand the analysed system with additional processes (UNEP, 2011).

2.10. Modelling GHG emission on a dairy farm

Dairy animals release GHGs during digestion of feed with further emissions during handling of their manure. GHGs from dairy farms include carbon dioxide, methane and nitrous oxide. Emissions are very dependent upon farm management, the climate and other factors, so large differences can occur among farms. Relationships for predicting all-important sources and sinks of the three GHgs on dairy farms were combined in a comprehensive model that predicts farm emission in CO2eq units (Figure 7) (Rotz et al., 2010).

Figure 7. life cycle assessment model of Ethiopian in dairy chain



Source: De Vries et al., 2016

2.11. Business Model CANVAS

According to Zott and Amit (2009), business model can be viewed as a template of how a firm performs a business, how it delivers value to stakeholders (customers, partners, etc.), and how it links factors and product markets. It involves a complex set of activities among multiple players which can lead to competitive advantage (Zott et al., 2011). The business model is a template that describes the organisation transactions with all of its external components in factor and product markets (Zott and Amit 2010). One of the most popular business model tools in recent years has been the 'Business Model Canvas', which was developed by Osterwalder and Pigneurs (2010). Its components are Value Proposition, Customer Segment, Customer Relationship, Channels, Key Activities, Key Resources, Key Partnership, Cost Structure, and Revenue Streams (Figure 8). The nine components cover the four main areas of business: customers, infrastructure, offer, and financial viability. The business model is a blueprint for a strategy to be executed through organisational structures, and systems and processes (Osterwalder and Pigneurs, 2010). In addition, Osterwalder and Pigneur established triple baseline (TBL) business models with a strong ecological and/or social mission that seeks to minimize negative social and environmental impacts and maximize the positive.

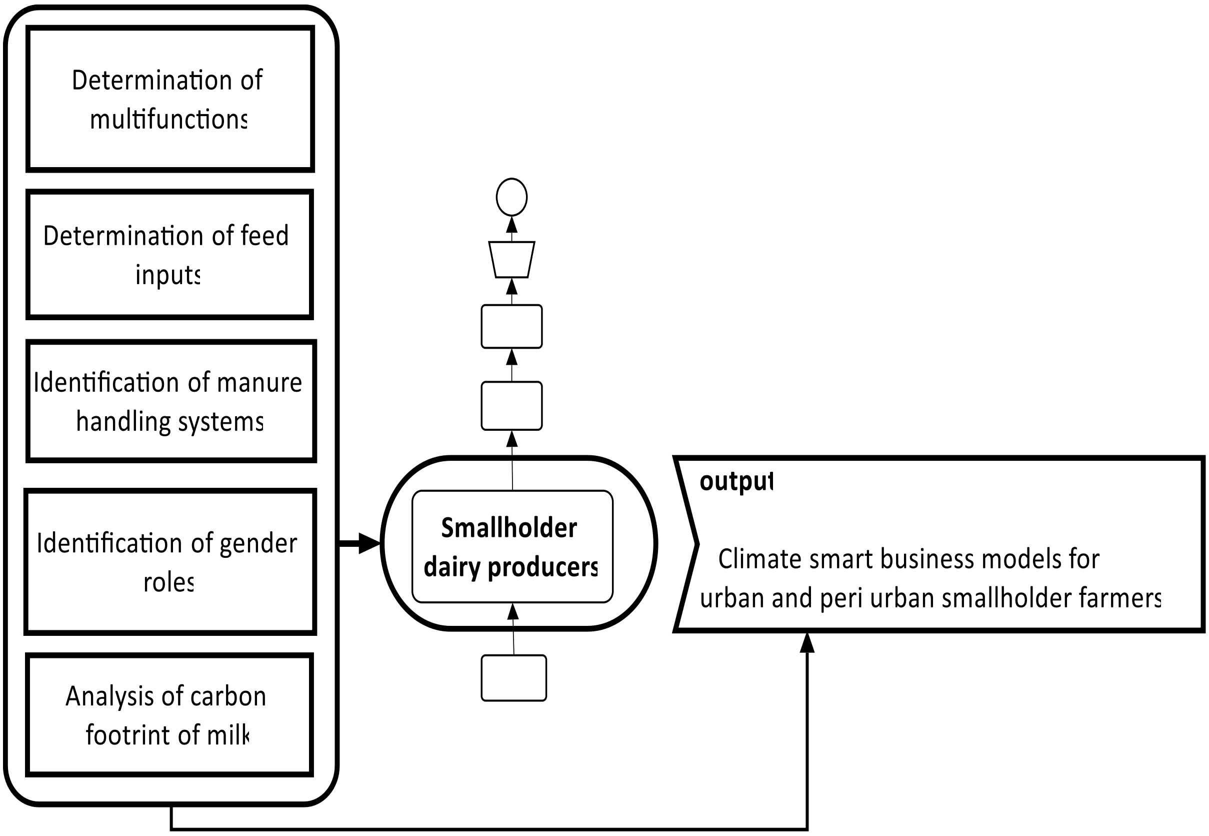
Figure 8. Triple baseline business model canvas

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

Source: Osterwalder and Pigneurs, 2010

2.12. Conceptual Framework

Figure 9. Conceptual framework



source: Author sketch

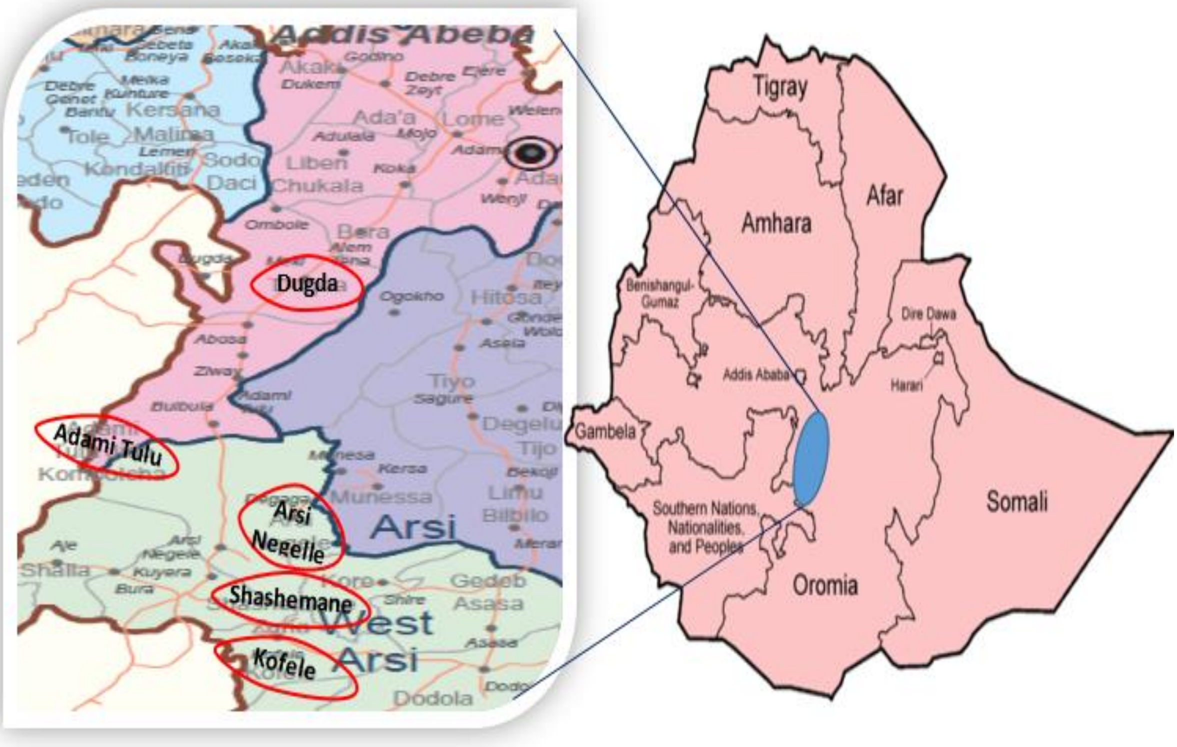
CHAPTER THREE: METHODOLOGY

3. Method of quantification, data collection and analysis

3.1. Study area description

This study centred on Zeway -Hawassa milk shed in Ethiopia. The shed is located on Addis Ababa to Hawassa highway, between 163 and 273 km south of Addis Ababa. Major towns found in the shed are Shashemane, Hawassa and Zeway (figure 10). The shed lays under central Rift Valley mainly in Oromia region, with altitudes ranging from 1500 to 2600 m.a.s.l.. The Rift Valley has an erratic, unreliable and low rainfall averaging between 500 and 1300 mm per annum. The temperature in the rift valley varies from 12-27^{0}C. Crop-livestock mixed farming is the dominant production system in these areas. Major crops grown around the area are cereals such as barley, teff, maize, wheat, sorghum, and root crops like sweet potato and potato and vegetables such as spinach, cabbage and onion as cash crops. An estimated total of 9,6 million litres of milk was produced annually from 4463 small and medium farms in the four towns (Hawassa, Shashemane, Zeway and Dilla). The majority of producers in the shed (61.7%) in the mixed farming system process milk at home, however, the majority of urban producers (79.2%) produce milk for sale (Chalchissa et al., 2014, Negash et al., 2012 and Yigrem et al., 2008).

Figure 10. Map of research districts in the Zeway- Hawassa milk shed



Source: Adopted from Oromia Region Administrative Map

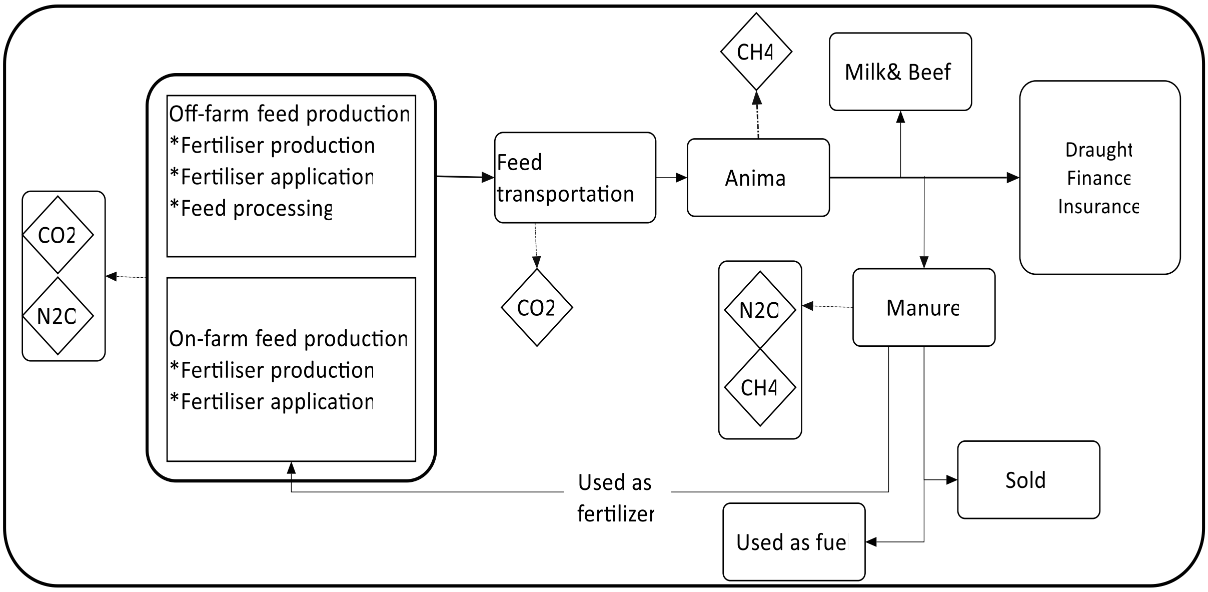
3.2. Research approach

Life cycle analysis (LCA) was used to quantify greenhouse gas emission associated with the production of milk in the current situation. Attributional life cycle assessment method was used since this method uses allocation for different functions, suited to the current milk production scenario where smallholder farmers keep cattle for multifunction.

3.2.1. System boundaries and functional unit

A carbon footprint (CF) is a single-issue LCA, focussing only on the emission of GHGs. In this study, the GHG emissions were quantified for all processes involved up to the farm-gate, including feed production, transportation, the animals (enteric emission), and manure management (Figure 11). The CF assessment of milk considered emissions under current smallholder production in multi-functional use conditions. The multi-functionality of the dairy production in the current milk shed required economic allocation for each purpose (output) that the animals kept which is essential to determine the share of emissions from each function. The functional unit of different dairy cattle functions was kg of carbon dioxide equivalents ($KgCO_2eq$) to produce a litre raw milk, a kg of beef, an hour of draught power, a kg of manure use and Finance and insurance of 100 ETB.

Figure 11. System boundaries for LCA in Ziway-Hawassa milk shade

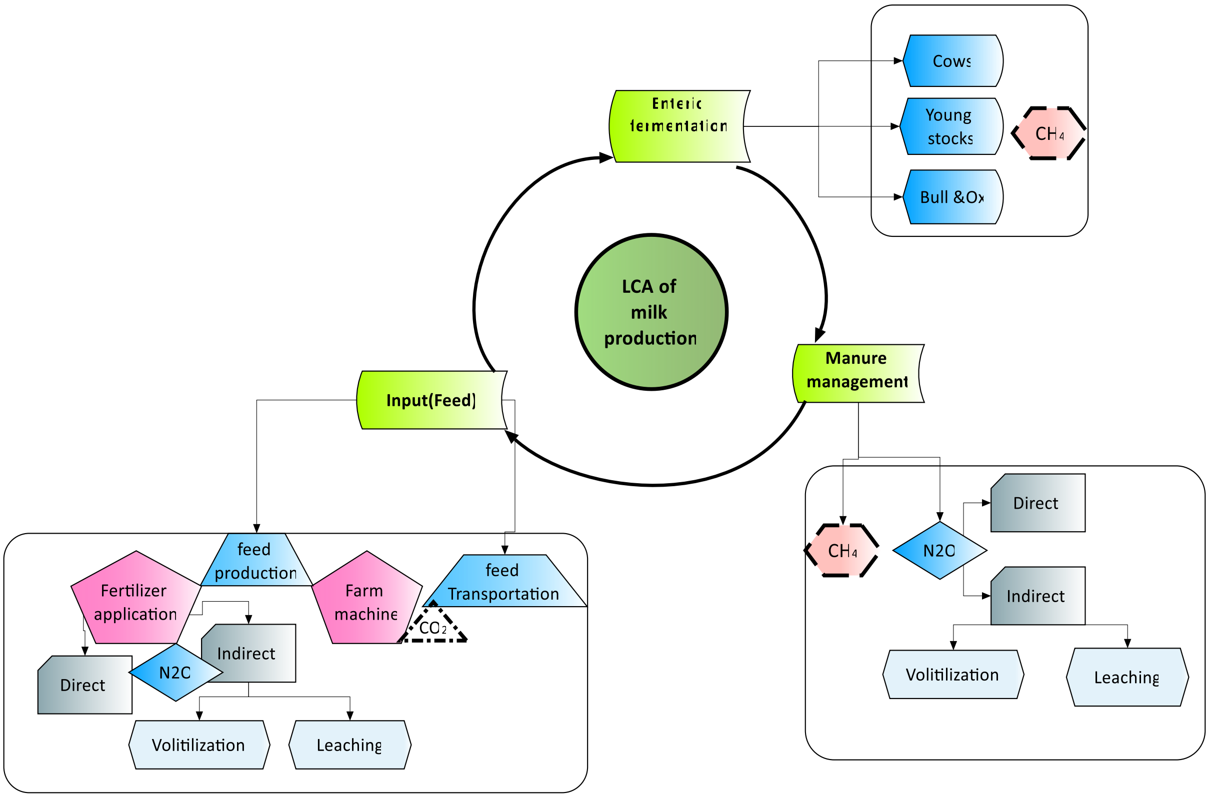


Source: Author sketch

3.2.2. Quantification of greenhouse gas emissions

This study considered three different emission sources; cattle feed production and transportation, enteric fermentation and manure management (Figure 12) for estimation of greenhouse gas emissions at smallholder dairy production

Figure 12. Sources of GHG emissions in LCA of milk production



Source: author sketch

Feed production and transportation

A. Feed production

Economic allocation was employed to assign the emission related to the use of crop residues; applied based on the economic value of the crop for human food use and the value of its by-products as cattle feed. These prices were based on current local market prices.

$$Crop = crop\ produce \times\ price$$

Where:

- Crop is the total economic value of the crop produced during one year (ETB);
- Crop produce was estimated as kg of crop produced on a farm per year, based on farmers' estimates.
- Price was based on the mean producer price of crop as paid by existing market

$$Crop\ residue = residue\ produce \times\ price$$

Where:

- Crop residue is the total economic value of the crop residue produced and offered for cattle during one year (ETB);
- Residue produce was estimated as kg of crop residue produced and provided to cattle per year, based on farmers' estimates.
- Price was based on the average producer price of crop as paid by existing market

In the process of feed production, two main sources were considered; one is from the use of fertilizer and the second source is from the use of farm machines.

1. Emissions from Fertilizer application

Direct and indirect methods were used to estimate total anthropogenic emissions of N_2O from managed soils. Tier 1 approach of IPCC was used to compute both direct and indirect emission of N_2O from managed soils.

A. Direct emission from crop production can be determined by direct emission of N_2O from synthetic and organic fertiliser application. Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the fertiliser. The following formula was adopted from IPCC guideline to compute direct N_2O emission from feed production from managed soils considering fertiliser application as an emission source.

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

Conversion of N_2O–N emissions to N_2O emissions was performed by using the following equation:

$$\boldsymbol{N_2O} = N_2O_{\_ND} * \frac{44}{28}$$

Where:

- $N_2O_{\_N\,D}$ = 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
- F_{ON} = 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).

B. Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO_x. Emissions of N_2O take place through two indirect pathways; i.e. **volatilisation and leaching**.

Volatilisation, N_2O (ATD)

The N_2O emissions from atmospheric deposition of N volatilised from managed soil was estimated using the equation below

$$\boldsymbol{N_2O_{(ADT)-N}} = [(F_{SN} * Frac_{(GASF)}) + (F_{ON} * Frac_{(GASM)})] * EF_4$$

Where:

- $N_2O_{(ATD)-N}$ = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils, kg N_2O–N per year,
- F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N per year
- F_{ON} = annual amount of organic fertiliser N applied to soils, kg N per year
- $Frac_{GASF}$ = fraction of synthetic fertiliser N that volatilises as NH_3 and NO_x, kg N volatilised per (kg of N applied)
- $Frac_{GASM}$ = fraction of Organic fertiliser N that volatilises as NH_3 and NO_x, kg N volatilised per (kg of N applied)
- EF_4 = 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–N volatilised)]

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

$$\boldsymbol{N_2O}_{(\boldsymbol{ADT})} = N_2O_{(ADT)\_N} * \frac{44}{28}$$

Leaching/Runoff, N_2O (L)

The N_2O emission from leaching was estimated using the following equation

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

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
- F_{SN} = annual amount of synthetic fertiliser N applied to soils in, kg N per year
- F_{ON} = annual amount of organic fertiliser N applied to soils, kg N per year
- $Frac_{LEACH-(H)}$ = fraction of all N added to/mineralised in managed that is lost through leaching and runoff, kg N per (kg of N additions)
- EF_5 = emission factor for N_2O 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 performed by using the following equation:

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

2. Emission from farm machinery

The second source of GHG emission in the feed production was from farm machines. Emissions that contributed by farm machine (used to plough land and for harvesting) were accounted for the combustion of fuel by the machine. The primary source of GHG emission from farming machine was CO_2. The following equation was adopted from IPCC guideline to determine GHG emission from fuel combustion.

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

Where:

- E_{fuel} = emissions 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).

Table 1. Emission factors of carbon dioxide per litre of fuel combusted in Ethiopia.

Source of emission	Emission factor
Gasoline	2.42kg CO_2/liter
Diesel	2.67kg CO_2/liter

Source: Gebre, 2016 and FDRE, 2011

B. Feed transportation

The following method was applied to estimate the carbon footprint of feed transportation

- ❖ The type of transport used, kilometres travelled, and the quantity of feed transported was determined (Table 2).
- ❖ The fuel consumption by the vehicle per kilometre and its full capacity of transportation was considered (Table 2).

- ❖ Allocation of fuel was made to find the quantity of fuel consumed only for a particular kilogram of feed that is transported together with other additional stuff by the same vehicle.
- ❖ Then, total estimated CO_2 emissions from feed transport were a product of the distance of feed transported, fuel consumption per kilometre and CO_2 emissions per litre of fuel.

$$Fuel = S \times L$$
$$E = Fuel \times EF$$

Where:

- Fuel is the total litres of fuel consumed by the vehicle to transport the feed to a certain distance (litres).
- S is the distance that the feed is transported (kilometres).
- L is the litres of fuel consumed by the vehicle to transport the feed to one kilometre distance(litres)
- E is the total emission from feed transport
- EF is the emission factor of CO_2 from fuel consumption

Table 2. Fuels types and distance travelled by different type of vehicles

Type of vehicle	Type of fuel consumed	Distance travel by litre of fuel (Km)
Motor bicycle	Gasoline	30
Bajaj (three-wheel vehicle	Gasoline	14
Minibus	Diesel	4
ISUZU	Diesel	4

Source: Authors survey data

Animal (enteric emission)

Depending on IPCC guideline Tier 2 Approach for methane emissions from enteric fermentation was used for the current study to quantify enteric emission. The Tier 2 approach was selected for the reason that enteric fermentation was a key source category for the animal category that represents a large portion of the total emissions. The amount of methane emission depends on age and the quality and quantity of the feed consumed. To specify the variation in emission rates among animals, the population of animals were divided into subgroups, and an emission rate per animal is estimated for each subgroup. To estimate enteric emission cattle were divided into three subgroups;

1. Cows,
2. Young stock and
3. Bulls and Ox.

For each of the representative animal subcategories defined, the following information was determined:

- ❖ Average daily feed intake (megajoules (MJ) per day and/or kg per day of dry matter); and
- ❖ Methane conversion factor (percentage of feed energy converted to methane).

The animal daily mount and type of feed intake was estimated by smallholder farmers for different cattle subgroups. According to the IPCC guideline methane conversion factor (Y_m) of cattle that are primarily fed low-quality crop residues and byproducts or grazing is taken as 6.5%. The equation presented below was used to determine the enteric methane emission factor.

$$EF = \left[\frac{GE * \left(\frac{\text{Ym}}{100}\right) * 365}{55.65} \right]$$

Where:

- EF = emission factor, kg CH_4 per head per year
- GE = gross energy intake, per head per year
- 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

$$\boldsymbol{Emissions} = EF * (N_T)$$

$$\boldsymbol{Total\ CH_{4enteric}} = \sum_{i} \boldsymbol{E_i}$$

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
- N_T = the number of heads of cattle / category
- T = species/category of livestock
- Total CH_4Enteric = total methane emissions from Enteric Fermentation, Kg CH_4 per year
- Ei = is the emissions for the *i*th cattle categories and subcategories

Manure management

a. Methane (CH_4)

Methane emission from manure management can be calculated by using the following equation as indicated by IPCC guideline.

$$\boldsymbol{CH_{4\,Manure}} = \sum \boldsymbol{EF_{(T)}} * \boldsymbol{N_{(T)}}$$

Where:

- CH_4Manure = CH_4 emissions from manure management, for a defined population, Kg CH_4 per year
- EF(T) = emission factor for the defined cattle population, kg CH_4 per head per year
- N(T) = the number of head of cattle /subcategory *T*
- T = subcategory of cattle

The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The Tier 2 method relies on two primary types of inputs that affect the calculation of methane emission factors from manure

1. **Manure characteristics:** Includes the quantity of volatile solids (VS) produced in the manure and the maximum amount of CH_4 able to be generated from that manure (Bo). Production of manure volatile solids can be estimated based on feed intake and digestibility. The VS content of manure equals the fraction of the diet consumed that is not digested and thus excreted as a faecal material which, when combined with urinary excretions, constitutes manure.

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

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 percent
- (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).

2. **Manure management system characteristics***:* Includes the types of systems used to manage manure and a system-specific methane conversion factor (MCF) that reflects the portion of B_o that is achieved. MCF is affected by the degree of anaerobic conditions present, the system temperature, and organic material retention time in the system. The default MCFs values will be taken by considering the manure management system and the temperature of the area. Default value 0.1 of methane producing capacity from manure (B_o) was taken as indicated in IPCC guideline.

   Based on Tier 2 approach of IPCC the following equation will be used for computation of emission factor.

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

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 per animal 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*, m3 CH_4 kg-1 of VS excreted
- 0.67 = conversion factor of m3 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

b. N_2O emission

N_2O emission was estimated directly and indirectly, during the storage and treatment of manure before it is applied. Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. Nitrification is likely to happen in stored animal manures provided there is a sufficient supply of oxygen. Nitrification does not occur under anaerobic conditions. Nitrites and nitrates are transformed to N_2O and dinitrogen (N_2) during the naturally occurring process of denitrification, an anaerobic process. Indirect emissions result from volatile nitrogen losses that occur mainly in the forms of ammonia and NO_x. The portion of excreted organic nitrogen that is mineralised to ammonia (NH_3) and nitrogen during manure collection and storage depends primarily on time, and to a lesser degree temperature.

Direct N_2O emission from manure management was based on the following equation:

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

Where:

- N_2OD (mm) = direct N_2O emissions from Manure Management, kg N_2O per year
- N(T) = number of he3ad of cattle/subcategory *T*
- Nex(T) = annual average N excretion per head /subcategory *T* , kg N per animal per year
- MS(T,S) = fraction of total annual nitrogen excretion for each animal/category *T* that is managed in manure management system *S*, dimensionless
- EF3(S) = emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O-N/kg N in manure management system *S*
- S = manure management system
- T = subcategory of cattle
- 44/28 = conversion of (N_2O-N)(mm) emissions to N_2O(mm) emissions

Indirect N_2O emissions from Manure Management

Tier 2 approach of IPCC guideline considers Nitrogen volatilisation in forms of NH_3 and NO_x from manure management systems which are based on multiplication of the amount of nitrogen excreted (from all cattle categories) and managed in each manure management system by a fraction of volatilised nitrogen

$$N_2O_{G(mm)} = (N_{volatilization-MMs} * EF_4) * \frac{44}{28}$$

Where:

- N_2OG(mm) = indirect N_2O emissions due to volatilization of Nitrogen from Manure Management, kg N_2O per year
- EF4 = emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N per (kg NH3-N + NOx-N volatilised)- ; default value is 0.01

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

Where:

- N volatilization-MMS = amount of manure nitrogen that is lost due to volatilisation of NH3 and NOx, kg N per year
- N(T) = number of head of cattle /category *T*
- Nex(T) = annual average Nitrogen excretion per head /category *T* , kg Nitrogen per animal per year
- 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 NH_3 and NO_x in the manure management system *S*, %

The indirect N_2O emissions based on tier two due to leaching from manure management systems (N_2OL (mm)) was estimated using the following Equation

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

Where:

- N_2O_L (mm) = indirect N_2O emissions due to leaching and runoff from Manure Management, kg N_2O per year
- EF_5 = emission factor for N_2O emissions from nitrogen leaching and runoff, kg N_2O-N/kg N leached and runoff

To determine the amount of 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) = number of 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 system *S*, dimensionless
- FracleachMS = percent of managed manure nitrogen losses for livestock category *T* due to runoff and leaching during solid and liquid storage of manure
- **Based on Tier one** approach of the IPCC guideline, annual nitrogen excretion rates can be computed by using the following formula

3.2.3. Economic allocation

In the current milk shed, dairy cattle were kept for multiple products. Economic allocation is commonly used in LCAs of dairy systems and denotes allocation of GHG emissions to the various cattle function (Weiler et al., 2014). The allocation method requires economic values of functions of cattle. Milk and meat have a direct market value, while the economic value of finance and cattle as a means of insurance and manure as fertiliser can only be assessed indirectly.

For this research study, economic function allocation was used where all products; i.e. milk, meat, manure as fertiliser, draught power, cattle as a means of finance and insurance (market and nonmarket products) were economically quantified.

The economic value of milk was calculated based on producer prices:

$$Milk = milkoutput \times milk\ price$$

Where:

- Milk is the total economic value of the milk produced from cattle during one year (ETB);
- Milk output was estimated as liters of milk produced per farm per year, based on farmers' estimates on milk consumed at home and milk sold.
- Milk price was based on the average producer price of milk as paid by existing market

The local rent value of an ox per year was used to determine the economic value of animals used for draught purpose.

$$Draught = rent \times H$$

Where:

- Draught is the economic value of cattle as draught during one year
- Rent is the economic value of a pair of oxen rented for draught purpose
- H is the number of hours the animal used for draught purposes per year.

The economic value of meat is calculated as a function of the animal category and the price per head

$$Meat = head \times price$$

Where:

- Meat is the total economic value of cattle utilised/sold for beef in one year (birr);
- Head is the type and number of cattle used for beef;
- Price is the producer price for the animal as paid by a local market.

In line with Weiler, 2014 the benefit of cattle for financing is related to the avoidance of paying an interest rate when borrowing money at a bank or from an informal moneylender:

$$\text{Finance} = \text{headprice} \times bf$$

Where:

- Finance is cattle economic value that used as finance per year (ETB);
- Head price is the economic value of cattle sold due to reasons of finance;
- *bf* is the interest rate.

The benefit of cattle as insurance is taken as the absence to pay a premium in case of insurance. A similar method was followed by Woldegebriel et al., 2017; the insurance value of cattle as an insurance for the household is estimated as the value of the stock on hand multiplied by an estimate of the insurance premium that farmers would have to pay for insurance equal to the capital value of their stock:

$$\text{Insurance} = \text{herdvalue} \times bi$$

Where:

- Insurance is the economic value of the cattle stock as an insurance for the household (ETB);
- herd value is the economic value of the cattle herd for one year;
- *bi* is the insurance premium

According to Alary et al. (2011), the economic value of manure as fertiliser is valued based on synthetic nitrogen fertiliser equivalents. The economic value of nitrogen was based on the local price of nitrogen in synthetic fertiliser

$$Manure = fertilizer\ price \times N\ in\ manure$$

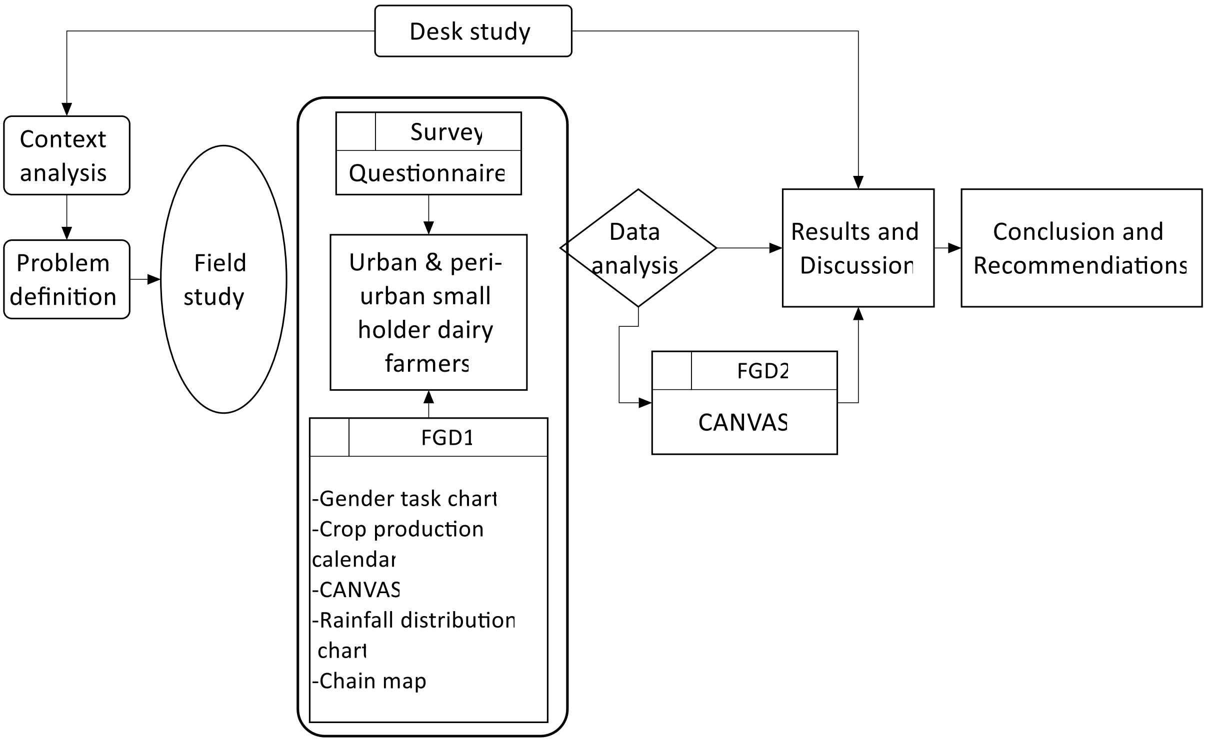
Where:

- Manure is the economic value of manure that used as fertiliser in a year (ETB),
- Fertiliser price is the economic value of N in synthetic fertiliser (ETB/kg);
- N in manure is kg N in manure used as fertiliser.

Nitrogen in manure used for fertilising was computed by multiplying the amounts of manure applied to crops based on farmers' estimates and the nitrogen content in cattle manure (1.4% will be taken for this study as used by Weiler et al., (2014).

3.3.4. Research framework

Figure 13. Research framework



Source: Author sketch

3.3.5. Research Design

Quantitative research design was used to undertake the current study. Herd composition, ranking of dairy cattle based on the functions, the quantity of milk production, amount and type of feed offered for dairy cattle, are the centre for this study. GHG emissions from different sources based on multi-functions of dairy cattle were estimated.

3.3.6. Methods of data collection

Desk research

A desk study was used to describe the context, to define the research problem as well as to make a review on the research topic that assists in comparing the result of this research. Desk research was also carried out to design the methods on quantification of GHGs (allocation procedures, emission factors and formulas) on smallholder dairy production for multipurpose production.

Participatory research method

The research team conducted two main stakeholder meeting as interance and closing sessions. The concept of research topic was explained at first stakeholder meeting while the output of the research was presented during the second stakeholder meeting. Focus group discussion (FGD) with urban and peri-urban smallholder dairy farmers were conducted at Zeway and Shashemane. The research team that focused on smallholder farmers combined the methods and tools in FGD to ease the discussion. On average ten dairy farmers were involved from Adami Tulu and Dugda districts at Adamitulu and from Arsi Negelle, Shashemane and Kofele at Shashemane. In the first FGD, research topic was discussed, and business models were constructed while the second was used to discuss on the new and proposed business models. Also, farmer group discussion was used to triangulate data collected by the questionnaire. CANVAS business model, feed production calendar, rainfall distribution chart and Gender task chart in dairy production were used as tools to lead farmer group discussion.

Survey

A structured questionnaire was used as a data collection tool to gather information from eighty (80) urban (51) and peri-urban (29) smallholder dairy producers in the shed. The questionnaire for this particular study and the questionnaire for one of the research topics on smallholder farmers was prepared and combined together to have a comprehensive list of questions for the two research studies. The two research team members collected data from the smallholder farmers using the comprehensive questionnaire. Each research member conducted a survey on forty (40) urban and peri-urban smallholder farmers, totally eighty smallholder farmers were surveyed for each of the research topics. Survey was used to answer the sub research questions of the first main research question of this study while the sub research questions of the second main research question were answered based on the data of the first main research question. The research team used a translator for local language during the survey.

3.3.7. Research Units

The research used sample districts in Oromia region in two different administrative zones (West Arsi and East Shewa zones). Shashemane, Arsi -Negelle and Kofelle districts were taken from West Arsi zone while Adami Tulu and Dugda district from East Shewa zone purposely by their milk production and supply in the shed as well as the interest of the commissioner. From each district, 16 smallholder dairy producers were selected deliberately considering urban and peri-urban dairy production systems. Urban dairy farmers were farmers who produce milk in the town, better access to market and delivered more milk to market. Peri-urban dairy farmers taken were far from town (7-25 kilometres from town), less access to the market, supply less milk to market and use more milk for home consumption.

3.3.8. Method of data analysis

The collected data was organized, coded and filled in to excel spreadsheet. The current study used quantitative methods of data analysis. Statistical Package for Social Science (SPSS) software was used for data analysis. Descriptive statistics (mean, minimum, maximum) was applied to summarise and present data in graph, table and chart to compare between different producer groups (Table 3). Emission factors (Appendix 3) and Green House Gas emission estimation equations of different sources were applied from Intergovernmental Panel on Climate Change (IPCC, 2006) document to quantify GHG emission. CANVAS business model was used to design the existing and new business models. A statistical test (independent sample t-test and chi-square test) was applied to compare the carbon footprint of milk between both urban and peri-urban milk production.

Table 3. Methods of data collection and analysis for each sub research question

Research questions	Method /tool of data collection	Method of data analysis	
	As research team	As research team	Individual
1.1. What are the functions and milk production of dairy cattle in smallholder dairy farming?			
	Survey /questionnaire	Descriptive statistics	Index
1.2. What are the feed inputs for smallholder dairy farming in the current milk chain?			
	Survey /questionnaire FGD/Crop production calendar, rain distribution calendar	Descriptive statistics	
1.3. What is the manure utilisation and handling systems?			
	Survey /questionnaire	Descriptive statistics	X^2-test, index, independent t-test
1.4. What is the role of gender in climate-smart dairying?			
	Survey /questionnaire. FGD/, Gender task chart	Descriptive statistics	
2.1. What is the carbon footprint of multifunctionality?			
	Survey /questionnaire.		LCA, independent t-test, economic allocation
2.2. What is the carbon footprint of milk production?			
	Survey /questionnaire	CANVAS	LCA, independent t-test

CHAPTER FOUR: RESULTS

This chapter presents the main research findings of the survey and focus group discussion; section 4.1-4.9 are primarily based on survey data whereas section 4.10 and 4.11 is based on focus group discussion.

4. Production system, GHG emissions and Business models

4.1. Household characteristics

As presented in Table 4, majority of the farmers engaged in dairy production in the shed were males (62.7% in urban and 82.8% in peri-urban). In other words, females were involved in the dairy activity but not as a lead person in both urban and peri-urban production. In both production systems, youth were involved in the dairy sector, i.e. 23.5% and 20.7% of dairy farmers found under the age of 35 years in urban and peri-urban respectively. Majority of dairy farmers attended either primary or secondary education in both urban or peri-urban dairy production.

Table 4. Household characteristics

		Urban (%) (N=51)	Peri-urban (%) (N=29)
Sex	Male	62.7	82.8
	Female	37.3	17.2
Age (years)	24- 35	23.5	20.7
	36-45	37.3	44.8
	46-55	15.7	17.2
	Above 56	23.5	17.2
Education	Illiterate	19.6	6.9
	Primary	31.4	58.6
	Secondary	35.3	17.2
	Higher	13.7	17.2

N= number of respondents

4.2. Dairy production system

4.2.1. Herd structure

Since urban dairy farmers were milk production oriented than peri-urban farmers, they kept more (49%) milking cows than peri-urban farmers (47%). Urban farmers kept fewer ox and bulls. When looking at the number of cattle herd categories per farm bases, peri-urban farmers kept larger number than urban farmers (Table 5).

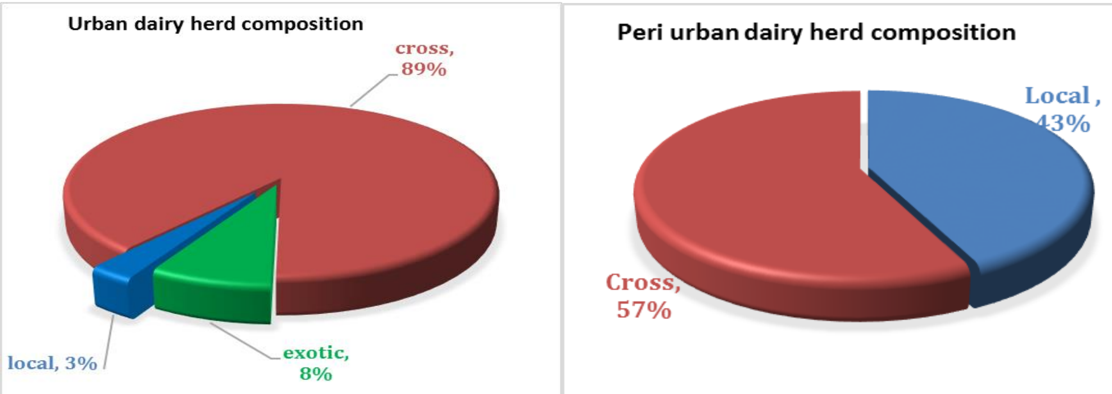
Table 5. Cattle herd category in urban and peri-urban production

Herd category	Urban			Peri-urban		
	N	%	Mean per farm	N	%	Average per farm
Milking cow	187	49	3.7	243	47	8.4
Ox	8	2	0.2	37	7	1.3
Bull	10	3	0.2	33	6	1.1
Heifer	93	24	1.8	101	19	3.5
Calf	87	23	1.7	106	20	3.7

N= Number of animals

As shown in Figure 14, the majority (89%) of dairy breeds in urban production were cross breeds (mostly different levels of Holstein Friesian with local cattle breeds). Pure local and exotic cattle breed in urban production accounted for 3% and 8% respectively. However, in peri-urban production, the dairy herd was composed of pure local breeds (43%) and cross breeds (57%) of local with exotic. Furthermore, peri-urban farmers were kept pure exotic breeds.

Figure 14. Herd breed composition in the urban and peri-urban production



Source: Author survey data (2018)

4.2.2. Farming system

As presented in Table 6, majority (72.5%) of dairy farmers in urban areas practice only livestock production where their major concern (80.4%) was for milk production from dairy cows. However, the reverse is true for peri-urban dairy farmers; they practised mixed type of farming system where both milk and crop production were closely equally important.

Table 6. Farming system and major farming activity

	Shashemene	Kofelle	Arsi Negelle	Adami Tulu	Dugda	Urban	Peri-urban
Farming system	%	%	%	%	%	%	%
Livestock	81.2	0.0	68.8	87.5	43.8	72.5	27.6
Crop livestock mixed	18.8	100	31.2	12.5	56.2	27.5	72.4
Major farm activity							
Milk production	81.2	37.5	81.2	87.5	62.5	80.4	51.7
Crop production	18.8	62.5	18.8	12.5	37.5	19.6	48.3

4.2.3. Multifunction of dairy cattle

As presented in table 7, in both urban and peri-urban areas cattle were kept primarily for their milk production. Urban dairy farmers next look for insurance and thirdly for financing the dairy business. In addition, in peri-urban production dairy farmers also raise cattle for draught purpose, a higher percentage than the urban farmers. This resulted from the mixed type of farming by peri-urban farmers.

Table 7. Functions of cattle in urban and peri-urban dairy production.

	Urban				Peri-Urban			
Function	R1	R2	R3	Index	R1	R2	R3	Index
Milk	51	0	0	0.57	27	2	0	0.53
Beef	0	2	5	0.03	0	2	3	0.04
Finance	0	18	7	0.16	2	10	1	0.17
Manure	0	1	1	0.01	0	0	2	0.01
Insurance	0	25	6	0.21	1	10	3	0.16
Draught	0	1	1	0.01	0	2	8	0.08

R1= first rank, R2 =second rank, R3=third rank, Index = $Index = \frac{\sum_n (3*R1)+(2*R2)+(1*R1)}{\sum_N (3*R1)+(2*R2)+(1*R1)}$, n=each function, N = all function.

4.2.4. Milk production

Table 8 shows the average milk yield in an urban and peri-urban production system. Urban farmers keep more crossbreed dairy cows, which yield more than local cows. As a result, urban dairy farmers obtain significantly large volume of milk per cow per day (12 litres) as well as per year (9260 litres) than the peri-urban dairy farmers. Furthermore, the milk produced in peri-urban system was mostly used for home consumption when compared to the urban system.

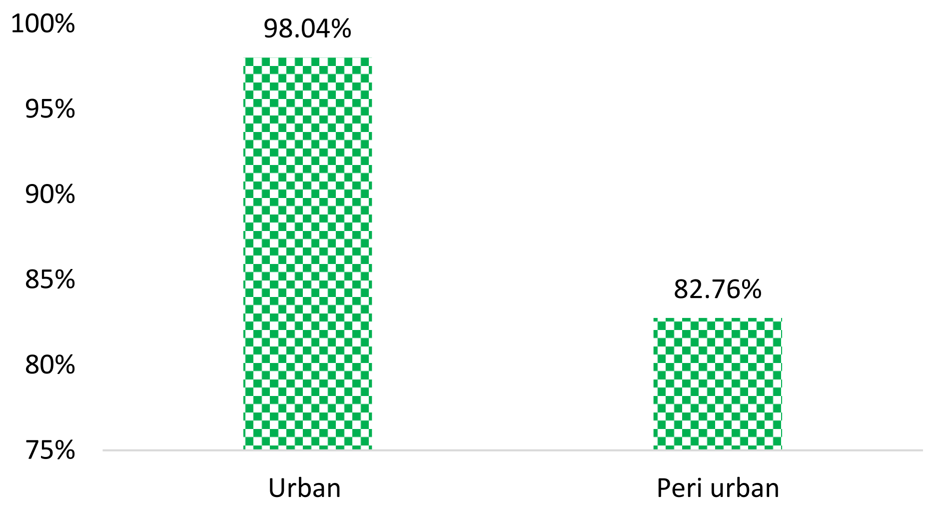
Table 8. Milk production in urban and peri-urban production

	Urban	Peri-urban	Sig. (2-tailed)
	Mean ± SE	Mean ± SE	
Milk yield per year per farm (litres)	9260±1.26*	5500±.88	.041
Milk yield per day per cow(litres)	12.02± .63*	6.59±.79	.000
Milk consumed at home per day(litres)	1.89± .27	5.32±.1.93*	.012

SE= Standard error *= significant at P<0.05

The majority (98.04%) of urban dairy farmers supply their milk to market always (Figure15). Peri-urban dairy farmers who supply milk to market always were about 82.76%. Even though the peri-urban dairy farmers sell milk, majority of the milk produced was consumed at home.

Figure 15. Milk sale in urban and peri-urban milk production



4.2.5. Feed sources

Majority of Urban dairy farmers provide dairy ration (51%), wheat straw (82.4%) and wheat bran (84.3%) than peri-urban farmers (Table 9). Peri-urban dairy farmers offer more barley straw and maize Stover. In addition, sugar cane molasses was provided only by peri-urban dairy farmers. In peri-urban dairy production, farmers allow dairy cattle to graze in addition to crop residues.

Table 9. Different feeds type of and major nutrient value

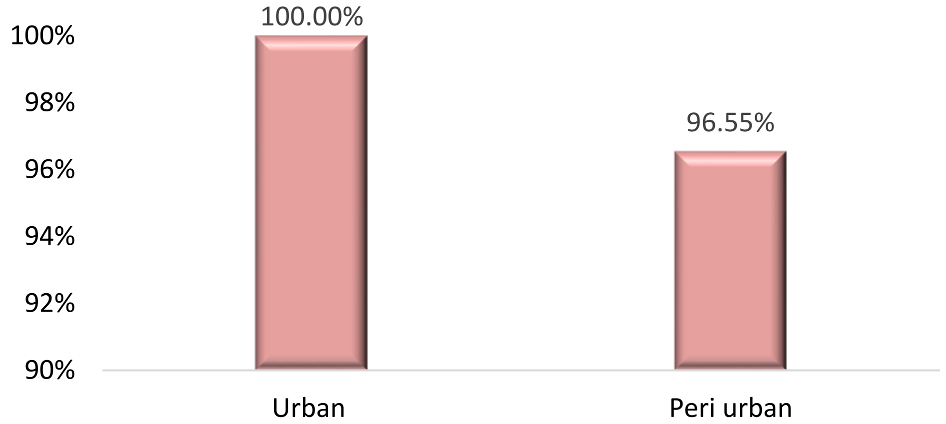
Type of feed	Urban (%)	Peri-urban (%)	DM (%fresh weight)	CP (%DM)	GE (MJ/kgDM
Green pasture	25.5	27.6	31.3	9.8	18
Maize green forage	25.5	27.6	23.3	7.9	18.2
Alfalfa green	3.9	3.4	90.6	18.3	18
Cabbage waste	2.0	3.4	9	23	18
Wheat straw	82.4	72.4	91	4.2	18.5
Teff straw	35.3	17.2	91.7	14.6	18.5
Barley straw	19.6	48.3	90.9	3.8	18.2
Maize stover	2.0	24.1	28.9	6.9	18.1
Lin seed meal	76.5	55.2	90.6	43.1	20.7
Wheat bran	84.3	69.0	87	17.3	18.9
Dairy ration	51.0	6.9	92.3	21	23
Cotton seed hull	2.0	10.3	90.6	5.1	19.6
Lentil bran	0.0	3.4	88.9	19.3	18.6
Nug seed cake	0.0	6.9	92.2	31.3	20.2
Atella	35.3	6.9	15.6	20	19.9
Sugarcane molases	0.0	10.3	73	5.5	14.7
Brewery grains	15.7	10.3	91	25.8	19.7

DM=dry matter, CP = crude protein, GE= Gross energy (source: Feedpedia)

4.2.6. Forage production

As depicted in Figure 16, the entire sampled urban dairy farmers did not produce forages to feed dairy cattle. They rely on buying different crop residues or concentrate feeds. Since most of the peri-urban farmers practised mixed farming, they only concerned to cultivate food crops (they use crop residues as animal feed). Very few (3.44%) peri-urban dairy farmers started to produce forages.

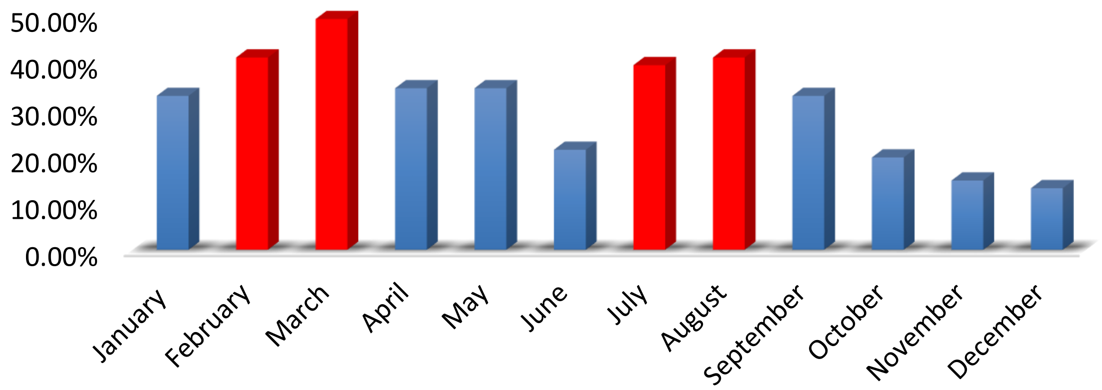
Figure 16. Proportion of farmers who did not produce Forage



4.2.7. Feed scarcity pattern throughout the year

As shown in Figure 17, majority of dairy farmers were agreed that February, March, July and August were months when feed scarcity was severe. During focus group discussion, farmers pointed that these four months are suitable for crop cultivation where most farmers engaged in crop production (with two different seasons). In other words, February, March, July and August were months where rainfall distribution is better than other months in the year. Therefore, in these months animal feed was more scarce than other months. Just after these four months, the degree of feed scarcity decreases. This is due to the availability of crop residues after crop harvest.

Figure 17. Feed scarcity and rainfall in months



4.2.8. Manure management and utilization

As depicted in table 10, more significant proportion of farmers (86.2%) in peri-urban area utilize or sell cattle manure than the urban farmers.

Table 10. Manure utilization in urban and peri-urban production

		Urban	Peri-urban
Do you utilize or sale cattle manure?	N	51	29
Yes	%	58.8	86.2*
No	%	41.2	13.8

*= significant at P<0.05

Table 11 shows different manure utilization purposes and selling. Majority (63%) of the urban dairy farmers used cattle manure for fuel as dried dung cake. Similarly, (but in a lesser extent) peri-urban farmers also used manure for fuel as dried dung cake. The peri-urban farmers mostly apply manure on arable land as a fertilizer since majority of them cultivate crops. Using manure for biogas was not quite common practice in both farming. However, the urban farmers had better initiation towards biogas utilization.

Table 11. Different manure utilization in urban and peri urban

	Urban				Peri-Urban			
Application	R1	R2	R3	Index	R1	R2	R3	Index
Crop fertilizer	4	2		0.16	7	9		0.37
Biogas	5			0.15				0.00
Dug cake for fuel	19	4		0.63	16	5		0.55
Construction			1	0.01		1	1	0.03
Sale	2			0.06	2			0.06

R1= first rank, R2 =second rank, R3=third rank, Index = $Index = \frac{\sum_n (3*R1)+(2*R2)+(1*R1)}{\sum_N (3*R1)+(2*R2)+(1*R1)}$, n=each function, N = all function.

Peri-urban dairy farmers managed manure for burning fuel more commonly than urban farmers. However, in urban areas manure was accumulated as a solid storage system (Figure 18) for a longer period of time than in peri-urban areas. Additionally, management of manure as compost was almost equally practised by both urban and peri-urban dairy farmers (Table 12).

Figure 18. Major manure management system; Burned for fuel (left) and as solid storage (right)

Table 12. Manure management systems in Zeway-Shashemane milk shade

	Urban		Peri-urban	
Management	Farmers (%)	Duration (Months)	Farmers (%)	Duration (Months)
Daily spread	0.0	0	3.4	12
Anaerobic digester	9.8	12	0.0	0
Burned for fuel	43.1	5.95	72.4	5.90
Composting	2.0	12	3.4	12
Solid storage	88.2	8.39	89.7	5.8

Source: Author survey data (2018)

As indicated in Table 13 total manure produced from all sampled farms in urban and peri-urban was 30,771.6 and 42,393.6 Kg dry matter per year respectively. From those total manures produced major portions were managed under solid storage system, 62% and 51% in urban and peri-urban dairy production. None of the manure was managed as a daily spread in urban and as anaerobic digester in peri-urban.

Table 13. Amount of manure managed under different management system

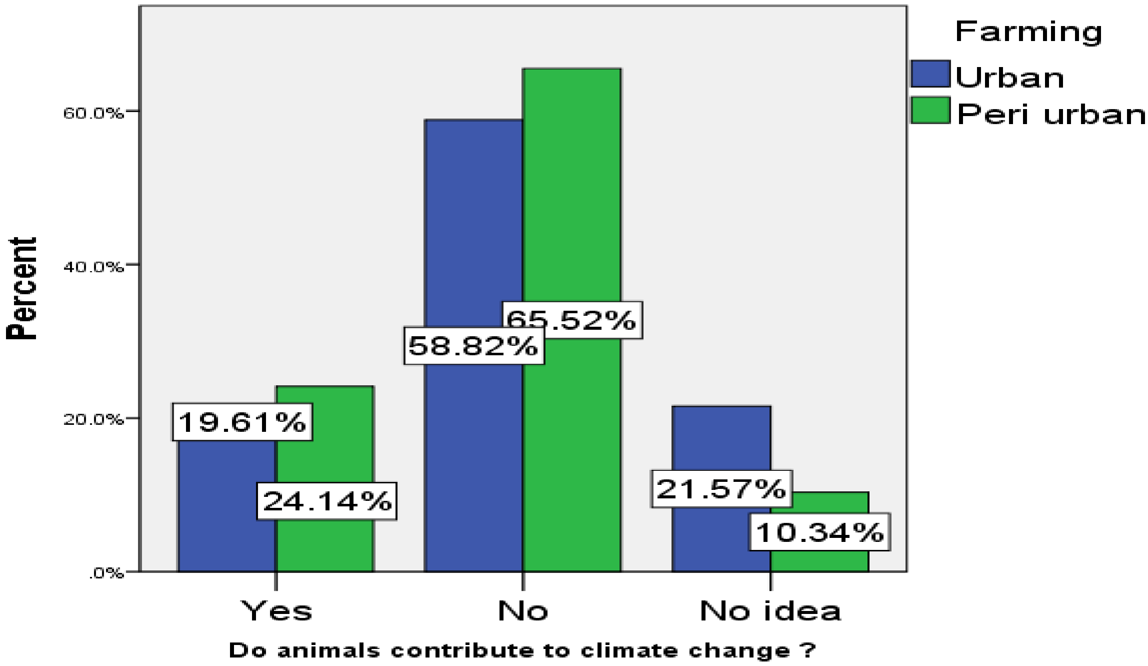
	Urban		Peri-urban	
Management	Amount (KgDM/year)	(%)	Amount (KgDM/year)	(%)
Daily spread	0.00	0.00	3326.4	7.85
Anaerobic digester	5328.00	17.31	0.00	0.00
Burned for fuel	5946	19.32	17294.40	40.79
Composting	345.60	1.12	144.00	0.34
Solid storage	19152.00	62.24	21628.80	51.02
Total	30771.6	100.00	42393.6	100.00

Source: Author survey data (2018)

4.3. Awareness on Animal emission

Majority of urban (58.82%) and peri-urban (65.52%) dairy farmers in the current milk shed believed that animals do not have any contributions to climate change (Figure 19). Few of dairy farmers (21.57% in urban and 10.34% in peri-urban) also had no any idea about emission from animals and their contribution to climate change.

Figure 19. Perception of dairy farmers towards climate change due to animals



4.4. Gender involvement in dairy production

Females participated in climate-smart activities in urban dairy production even though men took the lead (Table 14). More males were involved in feed selection, transportation, attending cows and select for breeding; husbands carried out most of these activities. Females have better contributions in milk processing at home and milk selling, mostly undertaken by wifes. The urban farmers did not practice feed preservation methods such as hay and silage making.

Table 14. Activities undertaken by household members in urban production

Activities	Husband	Wife	Daughter	Son	Male labourer	Female labourer
Manure collection	45.10%	49.02%	23.53%	39.22%	0.00%	0.00%
Manure application	3.92%	3.92%	0.00%	7.84%	11.76%	0.00%
Hay making	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Silage making	0.00%	0.00%	0.00%	1.96%	0.00%	0.00%
Feed selection	58.82%	45.10%	1.96%	19.61%	9.80%	0.00%
Feed transportation by cart	54.90%	37.25%	9.80%	23.53%	13.73%	0.00%
Attending and selecting cows for breeding	70.59%	41.18%	1.96%	13.73%	9.80%	0.00%
Milk selling	29.41%	66.67%	25.49%	19.61%	5.88%	0.00%
Milk processing at home	3.92%	27.45%	11.76%	5.88%	0.00%	3.92%
Milking	29.41%	47.06%	15.69%	21.57%	21.57%	7.84%

Unlike urban dairy production, in peri-urban female farmers were in the lead to undertake different activities. Manure collection from animal barns, milking, feed selection and milk processing at home were the major activities which were done by females (Table 15). However, selecting cows for breeding was continued to be a task performed by men (husbands). Peri-urban farmers never did silage for periods where feed was scarce.

Table 15. Activities undertaken by household members in peri-urban production

Activities	Husband	Wife	Daughter	Son	Male labourer	Female labourer
Manure collection	27.59%	62.07%	51.72%	24.14%	20.69%	3.45%
Manure application	24.14%	20.69%	17.24%	27.59%	6.90%	3.45%
Feeding animals	62.07%	62.07%	48.28%	58.62%	20.69%	
Hay making	10.34%	6.90%	6.90%	17.24%	0.00%	0.00%
Silage making	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Feed selection	68.97%	93.10%	0.00%	6.90%	3.45%	0.00%
Feed transportation	48.28%	37.93%	3.45%	13.79%	10.34%	
Attending and selecting cows for breeding	79.31%	27.59%	6.90%	17.24%	0.00%	0.00%
Milk selling	27.59%	65.52%	37.93%	20.69%	3.45%	0.00%
Milk processing at home	0.00%	72.41%	34.48%	0.00%	3.45%	3.45%
milking	13.79%	72.41%	20.69%	3.45%	17.24%	3.45%

4.5. Climate-smart dairy practices

From the above practices, most of dairy farmers practices climate-smart dairy even with less awareness about climate smartness. For example, manure application (fertiliser use) is practised mostly by peri-urban dairy farmers which is important in the circulation of nutrients in the farm. Selection of cows for breeding is also an attempt to change the genetic makeup of animals to improve productivity. Milk processing at home especially in peri-urban areas was also a try to convert surplus raw milk to non-perishable products in order to reduce milk wastage due to spoilage. In addition, as indicated in Figure 14, urban dairy farmers had few productive cross breed cows per farm which is also an attempt to reduce GHG emission per litre of milk production. Furthermore, few urban farmers practised better manure management as biogas which also reduces CH_4 emission from manure. Climate-smart feed transportation systems were observed in the current milk shade, i.e. transporting feed by locally available non-fuel consuming systems (horse or donkey cart).

4.6. Life cycle analysis

4.6.1. Emission from on-farm feed production

Most of urban dairy farmers did not produce animal feed rather depend on buying different forage and concentrate feeds. Off-farm feed production and processing were not accounted in both urban and peri-urban milk production in this study. Most of peri-urban dairy farmers offered crop residues for their cattle that obtained from cereal food cultivation. For those farmers who produce and offer crop residues for cattle, allocation was made to obtain the amount of GHGs emitted during crop residue production. Farmers who produce cereal crops estimated the amount of grains produced per hectare whereas the amount of crop residues produced per hectare was obtained from the literature. Crop residue production presented in Table 16 is based on Ethiopian climatic condition (Ketema, 1997). In addition, price per kilogram of grain and crop residue was estimated by farmers.

Table 16. Crop residue production and grain and crop residue price

Crop	Residue Production per hectare(tons)	Price per Kg of grain (ETB)	Price per Kg of crop residue (ETB)
Wheat	9	10.5	4.03
Barley	10	9	2.98
Teff	5	18	3.04
Maize	8	8	3.78

1 ETB= 32.13 euro

i. Emission from fertilizer application

Both synthetic and organic (manure) fertilizer application on soils for crop residue production were considered. The rates of both fertilizers applied were determined by crop producing farmers. Direct and indirect (volatilization and leaching) emission was computed per farm level for farmers who utilize either synthetic fertilizer or manure or both. Prior to the estimation of GHG emissions from crop residue production, the quantity of GHGs that released from cereal crop cultivation was first calculated from both fertilizer and farm machine utilization. As presented in Table 17 dairy farmers in both locations used both synthetic and organic fertilizer (cattle manure) for cereal crop production. Farmers were more dependent on synthetic fertilizers mainly Urea then followed by DAP (Diammonium phosphate). Urea fertilizer contains 46% nitrogen, and 18 % of nitrogen is available in DAP fertilizer. Cattle manure contains about 1.4% of nitrogen (Weiler et al., 2014). The total amount of nitrogen applied per year (2397 Kg) for crop production in peri-urban seems higher in urban dairy production. Nevertheless, it is lower when changed into farm level. However, urban dairy farmers apply more nitrogen per hectare than peri-urban farmers.

Table 17. Type and amount of fertilizer used for crop and residue production

Type of fertilizer	Urban		Peri-urban	
	Amount (Kg)	Nitrogen (Kg)	Amount (Kg)	Nitrogen (Kg)
DAP	4325	779	4228	761
Urea	3475	1599	2261	1040
Manure	1427	20	11465	161
Total nitrogen		2397		1962
Average Nitrogen per farm		47		68
Average Nitrogen per hectare		62		39

The overall GHG emission from fertilizer application for crop production in urban and peri-urban was 14,888 and 12,251 Kg eq CO_2 per year respectively (Table 18). The biggest contribution (75%) for this total emission was by a direct emission that occurs through combined denitrification and nitrification of nitrogen contained in the fertiliser. The indirect emission (volatilization and leaching) took the rest percentage contribution (25%) of the total emission from fertilizer application that resulted from volatile nitrogen losses that occur primarily in the forms of ammonia and other nitrogen compounds.

Table 18. Emission from fertilizer use for crop and residue production

	Urban Kg CO_2 eq/year)	Peri-urban Amount (KgCO_2 eq/year)
Direct	11225	9186
Volatilization	1132	994
Leaching	2526	2067
Synthetic fertilizer production	6	5
Overall	14888	12251
Average Per farm	292	422
Average per hectare	384	243

ii. Emission from farm machine

Farmers who used tractors and another machine for crop harvest also accounted for emission from farm machinery. The percentages of dairy farmers who used tractor and combine harvester were 3.9% and 9.8% in urban and 20.7% and 37.9% peri-urban (Table 19). Farmers preferred to use combine harvester at harvesting time than tractor during land preparation. The percentages of farmers that used farm machines for crop production (tractor and combine harvester) in the current milk shed were less. This is also manifested by small amount of total land size that was operated partly by farm machines, i.e. farmers used more animal traction and fewer farm machines.

Table 19. Use of farm machine to produce crops and crop residues

	Urban		Peri-urban	
Type of farm machine	Farmers (%)	Land size (ha)	Farmers (%)	Land size (ha)
Tractor	3.9	5.0	20.7	12.3
Combine harvester	9.8	6.5	37.9	20.3

Source: Author survey data (2018)

The overall emission from farm machine use in urban and peri-urban were 607 and 1465 Kg CO_2 eq./year respectively (Table 20). The overall emission from machine use in peri-urban production was more than double of the peri-urban emission. This is magnified when emissions from farm machine converted to farm level. In peri-urban milk production, the emission per farm from farm machine was 51 Kg CO_2 eq/year that is over 4 folds of the urban emission per farm.

Table 20. Emission from farm machine

	Urban		Peri-urban	
Type of machine	Fuel (liters)	(Kg CO_2 eq./year)	Fuel (liter)	Amount (KgCO2 eq./year)
Tractor	100	267	245	654
Combine harvester	128	340	304	811
Overall	228	607	549	1465
Per farm	5	12	19	51

iii. Allocation of emission to crop residue production

Table 21 presents the total amount of cereal crop grain and crop residue production per year and the economic return. Crop residues such as teff straw, wheat straw, barley straw and maize Stover were the four crop residues identified as feeds for dairy cattle during the survey. Wheat and maize were the top cereal crops dominantly cultivated by mixed dairy farmers in the shed. These crops were also the main cash generating crops for the dairy farmers. Crop residues from these two major crops also dominated in the shed that can be used as feed for dairy animals. To allocate the share of GHG emissions for crop residue production the proportion of economic importance of crop residues were computed. Thus, in the urban dairy production system crop residues accounted for 59% while in the peri-urban production the crop residue accounted for 54% of the economic return. Depending on these proportions GHG emissions from crop residue production were determined.

Table 21. Total production of crops and residues per year

		Urban		peri-urban	
		Production (kg)	Return (ETB)	Production (Kg)	Return (ETB)
Crop grain production	Teff	6,400	115,200	3,650	65,700
	Wheat	34,900	366,450	67,200	705,600
	Barley	5,100	45,900	26,000	234,000
	maiz	35,200	281,600	43,600	348,800
	Overall	81,600	809,150	140,450	1,354,100
Crop residue production	Teff	31250	95,000	17,500	53,200
	Wheat	132,750	534,983	213,750	861,413
	Barley	55,000	163,900	110,000	327,800
	Maiz	98,000	370,440	88,000	332,640
	Overall	317,000	1,164,323	429,250	1,575,053
All crop grain and residue return		398,600	1,973,473	569,700	2,929,153
% Return from crop residue			59%		54%

1 ETB= 32.13 euro

As shown in Table 22, the amount of GHG emission accounted for the production of crop residues as animal feed was 179 and 255 Kg CO_2 eq/year per farm level in urban and peri-urban respectively. The figures suggested that higher emission per farm per year from crop residue production was detected in periurban dairy production.

Table 22. Allocation of emissions for on-farm crop residue production

	Urban	Peri-urban
	(Kg CO_2 eq/year)	Amount (KgCO_2 eq/year)
Fertilizer use	14888	12251
Farm machine	607	1465
Overall	15489.5	13716
Allocation for crop residue	9142	7407
Average per farm	179	255

4.6.2. Emission from Off-farm feed production and processing

Emission of Off-farm feed production was estimated based on the quantity of concentrate feed offered to dairy cattle multiplied by emission per kilogram of concentrate feed production and processing. Emission related to off-farm concentrate feed production and processing of 1.36 KgCO2/Kg (Weiler et al., 2014) was taken for the current estimation. Therefore, emission per farm from off-farm feed production and processing was significantly higher in urban (4748 Kg CO_2 eq/year) dairy production (Table 23)

Table 23. Emission from off-farm feed production and processing

	Urban	Peri-urban
Concentrate feed (Kg/year	178068	46969
Emission (Kg CO_2 eq/year)	242173	63878
Average per farm	4748	2203

*= significant at P< 0.05

4.6.3. Emission from feed transport

As depicted in Table 24 and 25, the emission associated with feed transport were accounted from vehicles that consume fuel. In the urban dairy production emission, from feed transportation was calculated from Motor bicycle, Bajaj, Minibus and ISUZU vehicles while minibus and ISUZU were taken in to account for peri-urban dairy production because these were the only fuel consuming transporting vehicles in the area.

Table 24. Feed transportation systems used by urban dairy farmers

Transport system	Horse or donkey cart	Motor bicycle	Bajaj	Minibus	ISUZU	No or other means of transport
Type of feed	%	%	%	%	%	%
Green pasture	70.6	2	3.9	0	2	21.5
Wheat bran	80.4	2	2	0	0	15.6
Dairy ration	41.2	0	9.8	2	0	47
Cotton seed hull	5.9	0	0	0	0	94.1
Lentil seed bran	0	0	0	0	0	100
Nug seed cake	0	0	0	0	0	100
Wheat straw	52.9	0	0	0	23.5	23.6
Teff straw	17.6	0	0	0	7.8	74.6
Barley straw	7.8	0	0	0	3.9	88.3
Atella (distillery by product)	7.8	0	0	0	0	92.2
Maize green forage	5.9	0	0	0	0	94.1
Sugarcane molasses	3.9	0	0	0	0	96.1
Brewery grains	15.7	0	0	0	0	84.3
Cabbage waste	0	0	0	0	0	100
Green pasture	0	0	0	0	0	100
Alfalfa	0	0	0	0	0	100
Maize Stover	0	0	0	0	0	100
Average	18.22	0.24	0.92	0.12	2.19	78.32

The total kilometres of feed transportation by fuel consuming vehicles in urban and peri-urban dairy system per year were 3574 and 1344 respectively. Totally 517 and 336 litres of fuel was combusted during feed transportation within a year in urban and peri-urban respectively (Table 26). Minibus and ISUZU were the major diesel vehicles that dairy farmers used to transport animal feed. As presented in Table 26 the total emission from feed transport per farm in urban and peri-urban was 27 and 31 Kg CO_2eq/year.

Table 25. Feed transportation systems used by peri-urban dairy farmers

	Horse or donkey cart	Minibus	ISUZU	No or other means of transport
Type of feed	%	%	%	%
Green pasture	24.1	24.1	0	51.8
Wheat bran	55.2	10.3	3.5	31
Dairy ration	3.4	3.4	0	93.2
Cotton seed hull	10.3	6.9	0	82.8
Lentil seed bran	0	0	3.4	96.6
Nug seed cake	3.4	0	0	96.6
Wheat straw	17.2	0	3.4	79.4
Teff straw	3.4	0	0	96.6
Barley straw	13.8	0	0	86.2
Atella (distillery by product)	0	0	0	100
Maize green forage	13.8	0	0	86.2
Sugarcane molasses	3.4	0	6.9	89.7
Brewery grains	10.3	3.5	0	86.2
Cabbage waste	0	0	0	100
Green pasture	0	0	0	100
Alfalfa	0	0	0	100
Maize Stover	0	0	0	100
Average	9.3	2.8	1.0	86.8

The amount of CO_2 emitted per farm per year in feed transportation in the current location appears less. The majority of dairy farmers in both locations do not use any vehicle, or they use locally available transport (horse or donkey carts) for feed transportation (Table 24 and 25) that resulted in lower emission from feed transportation.

Table 26. Feed transportation and emission per year

Type of vehicle	Urban			Peri-urban		
	Kilometre	Fuel consumed (L)	Emission (Kg CO_2eq.)	Kilometre	Fuel consumed (L)	Emission (Kg CO_2eq.)
Motor bicycle	695	23	56	-	-	-
Bajaj	1262	90	218	-	-	-
Minibus	35	9	23	209	52	140
Isuzu	1582	395	1056	1135	284	757
Overall	3574	517	1353	1344	336	897
Average per farm	70	10	27	46	12	31

4.6.4. Enteric Emission

Type and quantity of animal feeds that offered for cattle were identified at the household level. Farmers estimated the amount of feed offered for cattle for different herd categories per day. The nutrient content of those different feedstuffs was obtained from online websites of Feedpedia (Table 9). The quantity of feed intake from grazing was difficult to estimate, and it was not accounted in the current enteric emission estimation. The total enteric carbon footprint from all sampled dairy farms in urban and peri-urban was 716729 and 672987 Kg CO_2eq per year (Table 27). When compared to other dairy herd categories cows contributed largest to the total enteric emission in both urban (74%) and peri-urban (66%) followed by young stocks and ox and bulls. The mean enteric emission from all herd categories per farm per year in peri-urban (23,206 Kg CO_2eq) production was significantly lower than the urban enteric emission (14,054Kg CO_2eq). However, the mean enteric emission per cow per year in urban production was 2967 Kg CO_2eq which is significantly larger than peri-urban enteric emission from cows per year per farm (2105 Kg CO_2eq).

Table 27. Enteric emission (Kg CO_2eq/year) contributed by different herd categories.

	Urban			Peri-urban		
	Total	Range	Average/farm	Total	Range	Average /farm
All cows	530161	1796- 42788	10395	442396	588-81922	12157^{NS}
All bulls and Ox	45446	0 -15559	891	71465	0-11229	2464*
All Young stocks	141121	0-16877	2767	159125	0-21684	5487*
Per cow	151329	638- 8660	2967*	61044	175-5461	2105
Per ox or bull	14764	0-5186	289	27168	0-4436	937*
Per youngstock	30618	0-2946	600^{NS}	14297	0-1524	493
All herd	716729	2260- 59665	14054	672987	662-81922	23206*

NS = Non-significant at P<0.05, * = significant at P<0.05

4.6.5. Emission from manure management

i. Methane emission from manure

The total annual methane emission from manure management from all sampled dairy farms in urban and peri-urban was 8329.81 and 5055.22 Kg CO_2 eq respectively (Table 28). Methane emission per farm from manure management system did not significantly differ between the two production systems.

Table 28. Methane emission from manure management system (Kg CO_2 eq./year)

	Urban	Peri-urban
Overall	8330	5055
Average per farm	163	174^{NS}

NS = Non-significant at P<0.05

ii. **Nitrous oxide emission**

The total direct and indirect nitrous oxide emission per year from manure management from sampled dairy farms was 1762 and 1850 KgCO_2eq in urban and peri-urban dairy production respectively (Table 29). In urban production a given dairy farm averagely released 35 KgCO_2eq per year while 64 KgCO_2eq per year was released by the peri-urban dairy farm specifically from manure management, significantly higher than the urban dairy farm.

Table 29. Emission from manure management

	Urban Kg CO_2 eq/year)	Peri-urban Amount (KgCO_2 eq/year)
Direct	651	718
Volatilization	687	653
Leaching	424	479
Overall	1762	1850
Average per farm	35	64*

*=significant at $P< 0.05$

4.6.6. Total emission from all sources

The overall annual emission from all emission sources from the sampled farms in urban and peri-urban production was 979,488 and 752,074 KgCO_2eq. respectively (Table 30). The average emission per farm in peri-urban was significantly larger than the peri-urban production. In other words, the emission per farm in peri-urban dairy production was twice higher than the urban dairy farm.

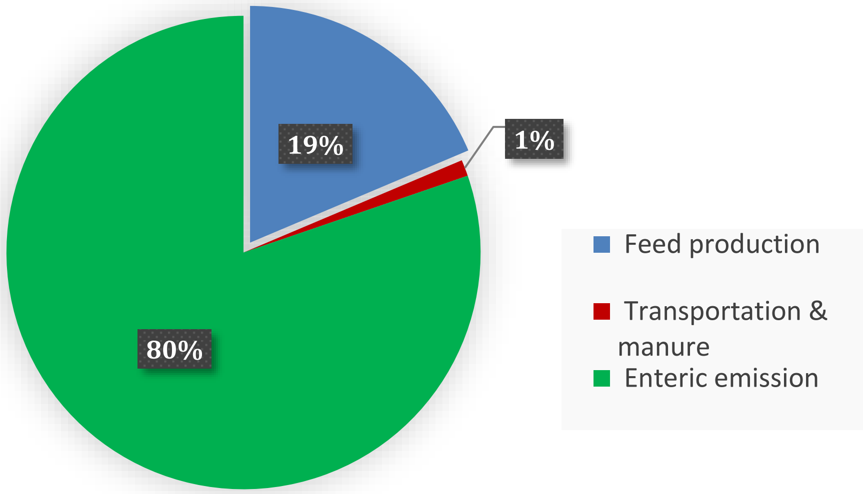
Table 30. Emission from all sources (Kg CO_2eq.)

	Urban	Peri-urban
Overall (per year)	979,488	752,074
Average per farm (per year)	19,206	25,934 *
Average Per liter	2.07	4.71 *

*=significant at $P< 0.05$

As depicted in Figure 20 the largest proportion of emission was contributed by the enteric methane emission. It accounted for about 80% of the total emission in the dairy sector in the current milk shade. Only 1% of the total emission was contributed by other sources (transportation and manure management).

Figure 20. Proportions of enteric emission with other sources



4.7. Economic value of dairy cattle

4.7.1. Economic value of cattle as milk

The total annual revenue from total milk production in urban and peri-urban milk production was 8.6 and 2.8 million ETB (Table 31). Milk revenue per farm for urban dairy farmer was over 70% of the peri-urban dairy farmer. This large significant difference mainly resulted from a large volume of milk production (9260 litres) per farm by urban dairy farmers.

Table 31. Economic value of milk (ETB)

	Urban	Peri-urban
Total milk production(liters/year)	472,260	159,630
Milk production per farm(liters/year)	9260*	5504.48
Total milk revenue per year	8,595,132	2,825,451
Revenue per farm per year	168,532*	97,429.34

*=significant at P=5%, 1 ETB= 32.13 euro

4.7.2. Economic value of cattle as beef

As presented in Table 32 the total live animal sold per year for beef purpose in urban dairy production was 385,300 ETB and 108,500 ETB in peri-urban production. Due to a higher number of cattle sold as beef in urban dairy production the amount of return was high even though the difference was insignificant.

Table 32. Economic value dairy cattle as beef

	Urban	Peri-urban
Total animal sale as beef per year	385,300	108,500
Revenue per farm per year	7554.90^{NS}	3741.37

NS = non-significant at P<0.05, 1 ETB= 32.13 euro

4.7.3. Economic value of cattle as draught power

The local rent value of ox used for draught purpose was obtained from dairy farmers during fieldwork. As reported by dairy cattle owners they normally pay 231 ETB for a pair of oxen used for six hours. As the same say, a pair of oxen served for draught purpose per hour by the value of 38.5 ETB. Since cattle served as draught purpose more commonly in peri-urban milk production, they have a large value of draught power estimated by rent value of the draught animal per year. Therefore, the total estimated value of draught power per year in urban and peri-urban was 81,689 and 129303 ETB respectively (Table 33).

Table 33. Draught animal service hours per year and rent value

	Per year	Urban	Peri-urban
Service period (Hours)	Total	2124	3362
	Average per farm	42	116
Economic value (ETB)	Total	81689	129303
	Average per farm	1602	4459*

*=significant at P<0.05, 1 ETB= 32.13 euro

4.7.4. Economic value of cattle manure

Manure sold, used as soil organic fertilizer and burned for fuel were quantified and valued in terms of economic importance for smallholder milk production system. Thus, the total economic value of manure from all sampled dairy farms in urban and peri-urban was 7330 ETB and 22542 ETB respectively (Table 34). Peri-urban dairy farmers commonly utilize manure as a source of fuel for cooking. Hence, the value of manure as fuel was high. In addition, the value of manure per farm per year in peri-urban farm was significantly larger than the urban farming

Table 34. Economic value of manure per year (ETB)

	Urban	Peri-urban
Sold	113	118
Used as fuel	6937	20177
Used as fertilizer	280	2247
Overall	7330	22542
Average per farm	144	777*

*=significant at P<0.05, 1 ETB= 32.13 euro

4.7.5. Economic value of cattle as finance

The economic value of cattle as finance is related to the avoidance of paying an interest rate when borrowing money at a bank or money lending institution. The microfinance institutions in the current production area apply 19% of interest rate when lending money to their customers. Hence, for the current study, the interest rate of 19% was used to determine the economic value of cattle as financing. The total annual cattle sold for reason of financing in urban was 586,500 ETB while in peri-urban was 200,000 ETB.

The total annual economic value of cattle as financing the dairy business from all sampled dairy farms in urban production was 111,435 ETB and 38,000 ETB in peri-urban(Table 35). When looking per farm level, the urban dairy farmer invested more in the dairy business when compared to the peri-urban dairy farmer.

Table 35. Economic value of cattle as financing (ETB)

	Per year	Urban	Peri-urban
Sold due to finance	Total	586,500	200,000
	Average per farm	11,500	6,896
Economic value	Total	111,435	38,000
	Average per farm	2,185	1,310

1 ETB= 32.13 euro

4.7.6. Economic value of cattle as insurance

The economic value of cattle as insurance is understood as the absence to pay a premium in case of insurance. Most insurance companies apply 6% insurance premium. Hence the premium rate of 6% was taken to calculate the economic value of cattle as insurance for the current study. All sampled dairy farms in the shed had cumulative herd value of 15,392,116 ETB and 14,591,240 ETB in urban and peri-urban. In different words, the total economic value of cattle as insurance in urban and peri-urban was 923,535 ETB and 875,477 ETB respectively (Table 36). The mean annual dairy cattle herd economic value as insurance in peri-urban farming was higher than the peri-urban.

Table 36. Economic value of cattle as insurance per year (ETB)

	Per year	Urban	Peri-urban
Herd value	Total	15,392,116	14,591,240
	Average per farm	301,806	503,146
Economic value	Total	923535	875,477
	Average per farm	181,09	301,89*

*****=significant at P<0.05, 1 ETB= 32.13 euro

4.8. Emissions of Multifunction

As presented earlier dairy farmers in the current milk shade kept cattle for different purposes (milk, beef, draught, manure, insurance and finance). Economic value for each of the functions that cattle served was computed. As presented in the Table 37 milk took the majority of dairy cattle herd value in both urban and peri-urban, i.e. it accounts about 85.06% and & 70.65% of all the functions that cattle serve in urban and peri-urban respectively. The share of GHG emission from different cattle purposes was allocated by the proportions of economic values. In urban dairy production, insurance, beef and finance took the next positions in the share of GHG emission next to milk production. However, insurance, draught and beef were in the order of sharing GHG emissions in peri-urban production after milk production.

Table 37. Allocation of emission for different functions of dairy cattle per year

	Urban			Peri-urban		
	Economic value (ETB)	%	($KgCO_2eq.$)	Economic value (ETB)	%	($KgCO_2eq.$)
Milk	8,595,132	85.06	833,183	2,825,451	70.65	531,334
Beef	385,300	3.81	37,350	108,500	2.71	20,404
Draught	81,689	0.81	7,919	129,303	3.23	24,316
Manure	7,330	0.07	711	22,542	0.56	4,239
Finance	111,435	1.10	10,802	38,000	0.95	7,146
Insurance	923,535	9.14	89,524	875,477	21.89	164,636
Total	10,104,421	100.00	97,9488	3,999,272	100.00	752,074

4.9. Carbon footprint of milk production

The carbon hotspot of milk production per farm per year in urban and peri-urban dairy production was 16,337 and 18,322 $KgCO_2eq$ respectively (Table 38). Furthermore, the carbon footprint per litre of milk production in peri-urban (3.33 $KgCO_2eq$) is higher than the urban (1.76 $KgCO_2eq$). Henceforth, allocation for different purposes in the current estimation took off about 14.94% and 29.35% of emissions in urban and peri-urban production respectively. Thus, allocation specified carbon footprint of milk production from 2.07 $kgCO_2$ eq./ liter to 1.76 $kgCO_2$ eq./ liter in urban dairy production and from 4.71 $kgCO_2$ eq./ liter to 3.33 $kgCO_2$ eq./ liter in peri-urban production. Therefore, allocation for different purposes of cattle keeping is important to remove biases when estimating emission per litre of milk production

Table 38. Total emission from milk production (Kg CO_2eq)

	Urban	Peri-urban
Total per year	833,183	531,334
Average per farm per year	16,337	18,322
Per liter	1.76	3.33

To make a fair comparison between the two production systems, all functions that dairy cattle served were seen per unit of measurement (Table 39). Hence, peri-urban dairy farms emitted higher GHGs when producing /providing different functions per unit.

Table 39. Emission per unit of functions

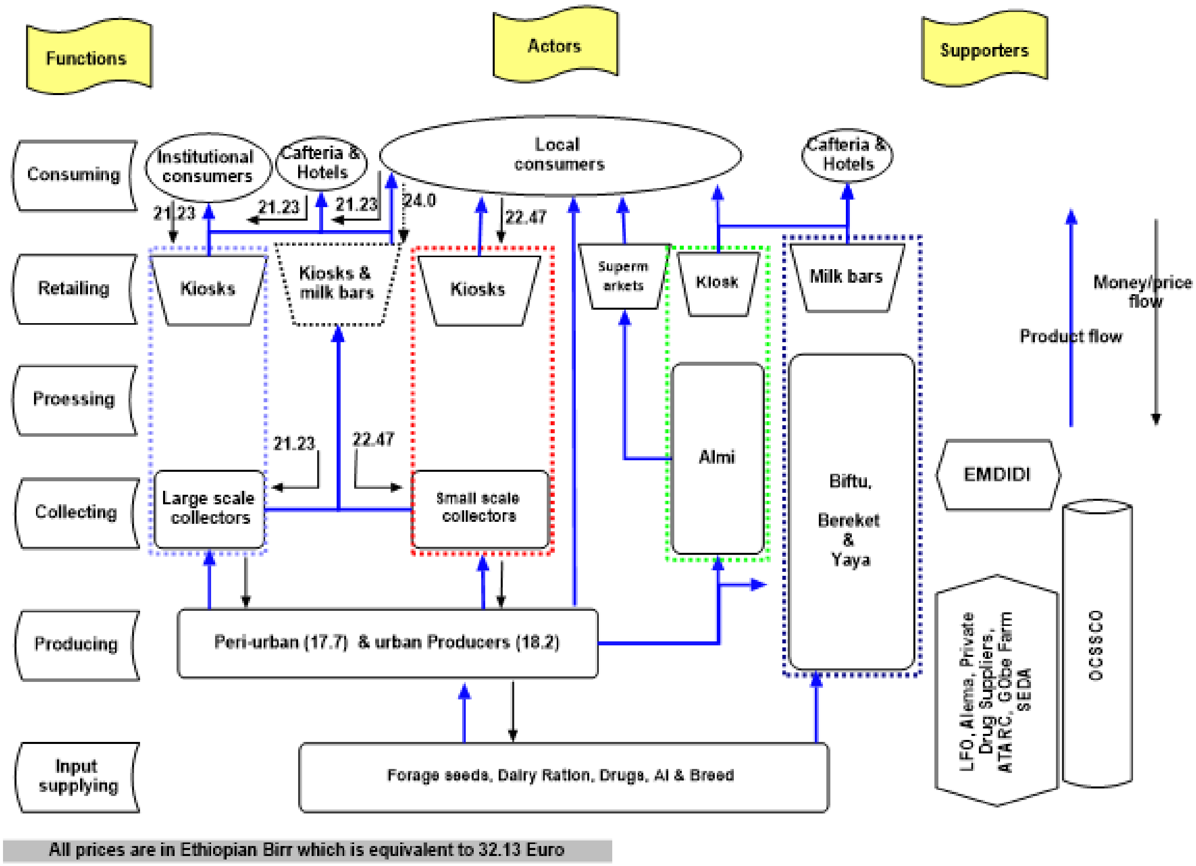
Function	Urban	Peri urban
A liter of raw milk	1.76	3.33
A Kg of beef	4.65	10.61
Finance of 100 ETB	1.84	3.57
A kg DM of manure utilized	0.06	0.20
An insurance of 100 ETB	0.58	1.13
An hour draught power	3.73	7.23

1 ETB= 32.13 euro

4.10. Dairy value chain map

During FGD, dairy farmers were mentioned that the feed input they used were crop residues (wheat, barley, teff straw and maize Stover), industrial byproducts (linseed meal, cotton seed hull, wheat bran) and local distillery byproduct (Atella). Urban and peri-urban dairy farmers were the main producers of milk in the chain. Small and large milk volume collectors collect from producers and sale to kiosks (Figure 21). Almi, Bereket Biftu and Yaya were milk processors controllig different function in the chain.

Figure 21. Value chain map in Ziway-Hawassa milk shade

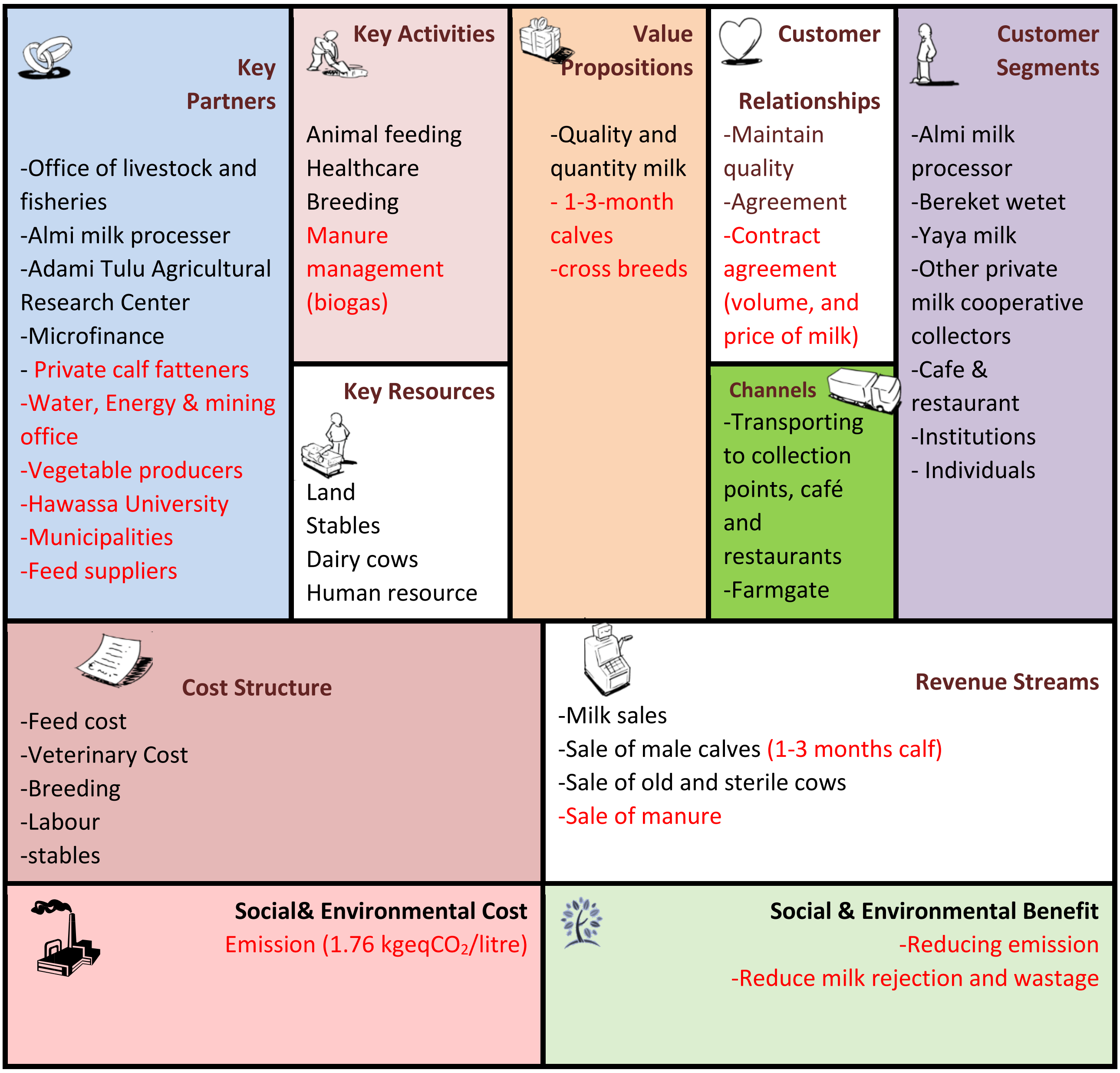


4.11. Business model CANVAS for smallholder dairy farmers

During FGD, urban and peri-urban dairy farmers have discussed their dairy business activities, and they constructed current CANVAS business model. Figure 22 shows CANVAS business model for urban dairy farmers. In key partners column, private calf fatteners were suggested as a new partner who could purchase extra calves or male caves from urban dairy farmers. This increases the value of calves particularly males. During FGD, Arsi Negelle farmers mentioned that they are interested in buying to grow or fatten calves as the area is also known for beef fattening activity by feeding locally available feeds especially Atella (distillery by-product of local liquor). Dairy farmers also agreed on the suggested linkage between water, energy and mining office and municipalities which solve the manure management problem. An expert from this office explained that biogas can be made in household bases with a small quantity of manure production (even from 2 animals) within limited space.

During FGD, farmers also pointed out that limited space was their main problem in urban. Hence, linkages with water, energy and mining office is important for farmers to get better technologies in manure management in with limited space. In addition, when farmers are organized, they have an opportunity to request land from municipalities. Therefore, better manure management system (biogas) is suggested as a new key activity. One to three-month calves is also additional value propositions and revenue streams.

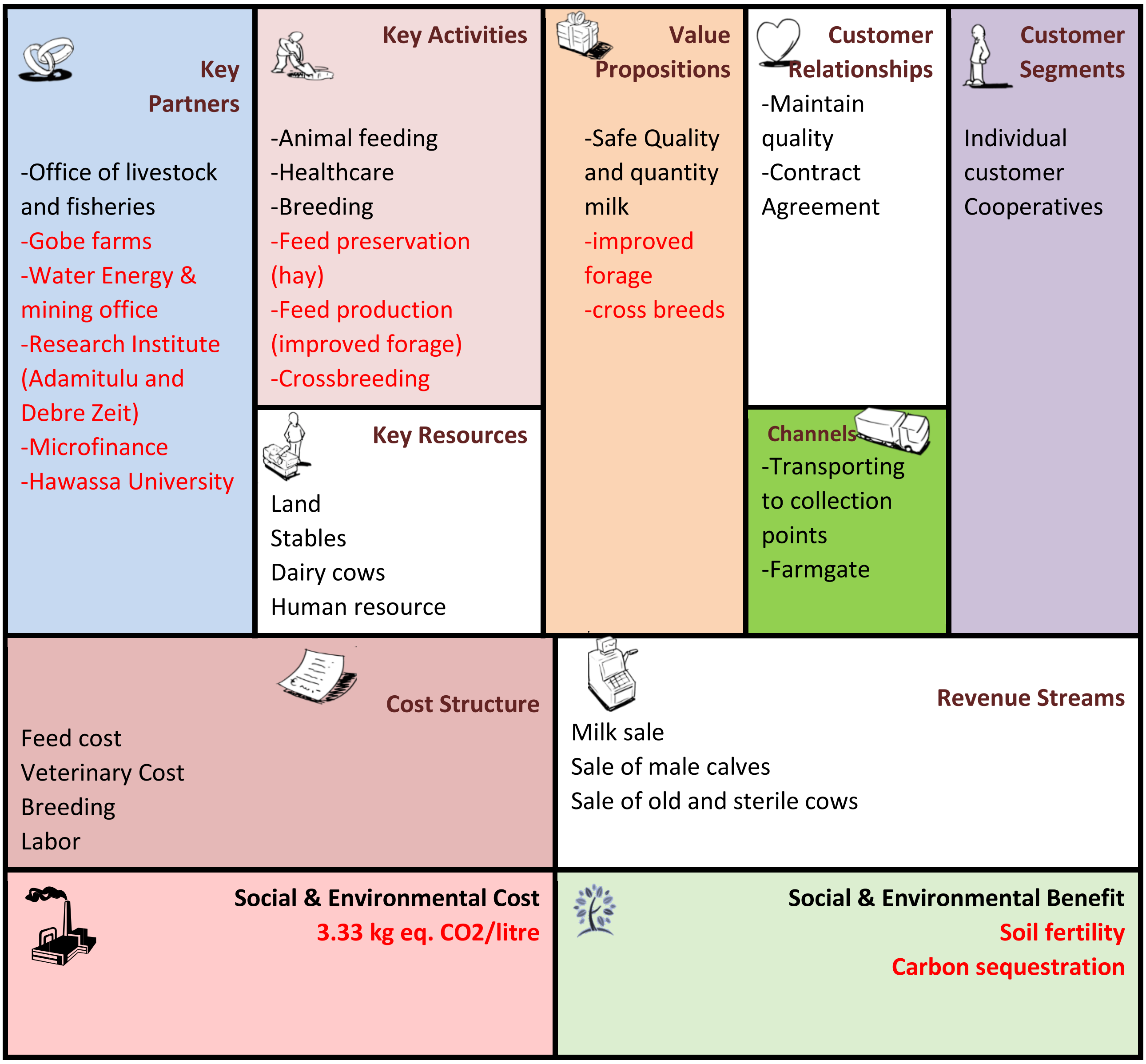
Figure 22. CANVAS business model for urban dairy farmers



Black colour represents the existed and the red colour represents the added.

The same holds true for peri-urban dairy farmers in making linkages with water, energy and mining office to extend manure management technologies (Figure 23). In key activities, feed production is suggested for peri-urban dairy farmers. Since peri-urban farmers are practising mixed farming, they can grow forage plants on sides of the main cropland as well as on private grazing lands protected only for grazing (observed during field data collection). Organized farmers have the strength to make links with research institutes for skill and input supplies.

Figure 23. CANVAS business model for peri-urban dairy farmers



Black colour represents the existed and the red colour represents the added.

CHAPTER FIVE: DISCUSSION

5.1. Dairy production system

Tegegne et al. (2013) reported that peri-urban dairy production usually practised mixed crop-livestock farming, which produced part of the feed in the form of crop residues and grazing. This agrees with peri-urban dairy farmers in Ziway- Hawassa milk shade, where majority (72%) of dairy farmers practised crop-livestock mixed system. Furthermore, 63% of the dairy cattle population was found in the mixed crop-livestock dairy system (FAO & NZAGRC, 2017). Unlike peri-urban dairy farmers, majority of urban dairy farmers were livestock production oriented where their major intention was milk production.

Majority (89%) of dairy cattle breeds in urban production in the current milk shade were cross breeds (Holstein Frisian with local cattle). This is because the urban farmers have relatively better access to services such as artificial insemination provided by the public and private sectors (Tegegne et al., 2013). Since urban farmers were milk production oriented, they kept more crossbreeds that give more milk than the local cows and also applied relatively better cow management. When looking to the country report CSA (2017) 98.2% of cattle in the country are local breeds while the rest 1.8 % were cross or exotic breeds. The result of the current study implies that majority of the crossbreeds on the country level is contributed by urban dairy farmers. Urban dairy farms of the current milk shade had higher crossbreeds (89%) than in Hawassa and Debre Birhan, reported by Mekuria (2016), where 42% of the dairy herd were Holstein Friesian cross.

An average herd size of milking cows per farm in urban was half of milking cows in peri-urban (they keep fewer milking cows than peri-urban farmers). However, milk production per cow was significantly higher than peri-urban (Table 8). Because urban dairy farmers focused on fluid milk production and sale with little land resources, using the available human and capital resources mostly under stall feeding conditions (Land O'Lakes Inc., 2010). In the current milk shade, total milk production per farm per year in the urban production system (9200Kg) was higher than Mekelle milk shade in Ethiopia; reported as 8900 kg by Woldegebriel (2017).

This study also revealed that the primary purpose of keeping cattle in the shed was milk production. This result agrees with Beriso et al. (2015) who reported the same for Aleta Chuko district in southern Ethiopia. The result of this study also consistent with Tegegne et al. (2013) who reported that in peri-urban production animals are also kept for manure (fuel production and fertilise the soil), and male animals are kept for draught power.

5.2. Gender involvement in dairy production

In urban dairy production females especially, wives (49%) undertake manure collection from barns which is consistent with Beriso et al. (2015) who reported that 50% of farmers agreed that women clean barns (collect manure) in Aleta Chuko. Even though Men (husbands) were the lead in undertaking feed selection and selection of cows for breeding women were also had shares in these activities. They played a better role in milking, milk selling and processing milk at home. Likewise, Beriso reported that milking of dairy cow was the job of women (80%). Additionally, the result agrees with Njarui et al., (2012) who reported that women contributed the highest labour in milking in peri-urban Machakos, Kenya. Labour is the key input in peri-urban dairying activities where milking, milk processing and barn cleaning were primarily done by women (Geleti et al., 2014).

However, the current result is in contrast with a report of Tasew and Seifu (2009) who found that milking of dairy cow was the job of men in Bahrdar, Ethiopia.

5.3. Feed resources and availability for dairy cattle

Majority of dairy farmers in the current milk shade provide crop residues mainly wheat straw in both urban (82.4%) and peri-urban (72.4) production for dairy cattle. However, barley straw and maize stover were more common feed in peri-urban dairy farming. This result is in line with Tadesse et al. (2015) and Ali et al. (2015) who reported that crop residues were the major feed resources for urban and peri-urban areas at Hosanna and for eastern Ethiopia respectively. Next to crop residues dairy farmers in the current milk shade also use industrial by-products. Wheat bran and linseed meal were the most common feed used for dairy cattle in both urban and peri-urban dairy production system. This result completely agrees with Yasar et al. (2016) who reported that Wheat bran and linseed meal were main feed supplements in urban and peri-urban areas in Bale zone of Oromia region. This result is also similar to Tadesse et al. (2015). However, it contrasts the report for Mecha woreda by Tasew and Seifu (2009) where communal grazing lands provide the major feed to cattle.

The use of improved forages for dairy cattle feed was not common in the current milk shade in both urban and peri-urban production which is consistent with the report of Tasew and Seifu (2009) for Mecha woreda dairy farmers. Urban dairy farmers had a higher tendency to provide dairy ration that was processed and distributed by Alema Koudijs Feed PLC for milking cows. The result of this study also showed that local distillery byproduct called Atella was commonly used by urban dairy farmers particularly in Arsi Negelle where distillation of local liquor is widely practised. This agrees with the result of Tasew and Seifu (2009) for Bahrdar Zaria and Mecha woreda dairy farmers. Dairy farmers offered feeds for dairy cattle mixing different feeds together for all kinds of herds nevertheless, dairy ration from Alema Koudijs was only offered for milking cows.

In the current milk shade, the degree of feed scarcity was high in February, March, July and August (Figure17). These months had better rainfall distribution and suitable for cultivation, so farmers cultivate crops in these months. Unlike the report of Tasew and Seifu (2009) and Tadesse et al. (2015) feed scarcity was severe in the rainy season than the dry periods for the current milk shade. This is because of a high degree of dependence on crop residues as cattle feed. In rainy seasons (especially months mentioned above) crop residues were scarce. After cultivation and harvest of crops the degree of feed scarcity getting reduced, i.e. crop residues are available as cattle feed.

5.4. Manure management

The result of this study revealed that majority (63%) of the urban dairy farmers used cattle manure for fuel as dried dung cake. Similarly, peri-urban farmers also used manure for fuel as dried dung cake and apply on soil when cultivating crops. This result is consistent with research report in Adigrat town, Ethiopia where manure was used as a source of fuel and important input for crop production and for nutrient recycling (Nigus et al., 2017). Lower percentages (37%) of dairy farmers in the current milk shade used manure as fertilizer when compared with Kenya where 90% of the smallholder dairy farmers used manure as a fertiliser on their land (Weiler et al., 2014). In peri-urban production, manure handling as biogas system was not practised, which is similar with dairy farmers in Adigrat. Majority of dairy farmers stored manure as solid storage in both urban and peri-urban production systems with longer duration (8 months) in urban. This result is inconsistent with Garg et al., 2016, who found that smallholder farmers in Anand district of western India stored manure for 2–4 months before it was utilized. Peri-urban farmers apply manure directly to crops as dairy spread without storing which is also similar to the report of the same author. Besides, few dairy farmers in Ziway-Hawassa milk shade also sale manure mainly as organic fertilizer, the same with the result of Woldegebriel et al. (2017) in Mekelle milk shade area.

The total amount of manure produced per farm in urban and peri-urban in the current milk shade was 603.34 and 1461.84 Kg DM per year. This is lower when compared with the result in Anand district in western India, 3067 Kg DM/year was produced per farm (Garg et al., 2016). It is also considerably lower than Kenyan smallholder dairy farms and urban or peri-urban dairy farms in Mekelle (Weiler et al., 2014 and Woldegebriel et al., 2017). Eight percent of the manure produced in peri-urban dairy production was utilized to fertilize cropland while the major portion was managed as solid storage and burned for fuel. This situation is totally different in Anand district of western India where a major portion of manure produced was used as crop fertilizer (Garg et al., 2016).

5.5. Green House gas emissions

5.5.1. Emission from feed production and transportation

The current study focused on emission from feed production (crop residue production) and off-farm feed production and processing. Almost all smallholder dairy farmers in the shed did not produce animal feed on the farm. Very few (3.44%) farmers were identified to produce forage. However, they used neither fertilizer nor farm machines. The total emission per farm per year from feed production and transportation in urban (4954 kgeq.CO_2) was higher than peri-urban (2489 kgeqCO_2) dairy production. Because urban dairy farmers mostly purchase animal feeds (they used more processed feeds) while peri-urban farmers used crop residues and no on-farm feed processing. Emission from feed production and processing in the current milk shade was higher than Kenyan smallholder dairy farms (1044.16 kgeqCO_2) (Weiler et al. 2014).

5.5.2. Enteric emission

The current study revealed that each urban and peri-urban dairy farm released an estimated enteric CH_4 of 14,054 KgCO_2eq/year and 23,206 KgCO_2eq/year respectively. This result is much higher than Kaptumo smallholder dairy farms in Kenya and in Anand district of western India where total enteric emissions per farm averaged 4437 kgCO_2eq/year (Weiler et al., 2014) and 10610 kgCO_2eq/year (Garg et al., 2016). This higher enteric emission resulted from higher number of cattle per farm and low-quality feed. Furthermore, the higher fraction of enteric methane emission was mostly related to the nature of ruminant digestion that was influenced by the quality of feed (Garg *et al*. 2013). In the current milk shade, enteric emission from cows contributed largest when compared with other herd categories. This was also related to the presence of higher number of cows per farm.

5.5.3. Emission from manure management.

Both CH_4 and N_2O emissions were considered from manure management systems. The current study revealed that emission per farm in urban and peri-urban production from manure management system averaged 198 kgCO_2eq/year and 238 kgCO_2eq/year respectively. Of which CH_4 accounted 163 kgCO_2eq/farm.year and 174 kgCO_2eq/farm.year in urban and peri-urban production. The current result is lower when compared with Kaptumo smallholders in Kenya; reported as 1040 KgCO_2 eq/farm.year where emission from manure accumulation on pasture accounted for 95% (Weiler et al., 2014). N_2O emission from manure management in the current milk shade is higher in peri-urban than in urban. The large quantity of manure production (resulted from higher number of cattle per household) in peri-urban dairy system contributed to the higher N_2O emission from manure management.

5.6. Economic value of Dairy animals

In the current milk shade, smallholder dairy farmers kept dairy cattle for multifunction (milk, beef, draught, manure, finance and insurance). Different function had their own economic importance. In such a scenario, economic function allocation was used to assign importance of functions and quantified in money terms (Weiler et al., 2014). All direct and indirect functions of dairy cattle kept under smallholders were quantified into economic values over a year period. The result of this study showed that in urban smallholder dairy farms, milk covers 85% of the entire functions that dairy cattle offered. This economic importance of milk was close to urban or peri-urban milk production in Mikelle milk shade where milk contributed about 80% of economic benefit (Woldegebriel et al., 2017). This result also comparable with a report of Weiler et al. (2014); milk contributed on average 82% to the economic value of a farm for Kaptumo smallholders in Kenya. Insurance (9.14%), beef (3.81%), finance (1.1%) draught power (0.81) and manure (0.07%) account the other 25% in order of economic contributions in urban dairy farms next to milk. In peri-urban dairy farms, milk contributed 70.65% of the economic benefit followed by insurance (21.89%), draught power (3.21%), beef (2.71%), finance (0.95%) and manure (0.56%) respectively. The percentage of economic contribution of manure and financing in the current milk shade were lower than the report of Weiler et al. (2014); manure and financing contributed 4% and 5.5% respectively. Nevertheless, insurance contributed larger in the current milk shade than Kaptumo smallholders in Kenya.

5.7. Carbon footprint of milk

Carbon footprint (CF) of milk production without allocation to other dairy cattle functions was 2.07 $KgCO_2eq$/ litre and 4.71 $KgCO_2eq$/ litre in urban and peri-urban production respectively. CF of milk in urban smallholder dairy farm is comparable with smallholder farms in Anand district (2.2 kg CO_2eq/kg FPCM) and urban dairy farm in Mekelle shade (2.25 kg CO_2eq/kg milk (Garg et al., 2016 and Woldegebriel et al., 2017). When allocating to other co-products(functions), the CF of milk production accounted about 85% and 70.06 % of the entire emission in urban and peri-urban production. Thus, an urban smallholder dairy farm averagely released 1.76 Kg CO_2eq/ litre while a peri-urban dairy farm released averagely 3.33 Kg CO_2eq/ litre. Therefore, the CF of milk reduced by 15% and 29.04% in urban and peri-urban smallholder dairy production. Similar pattern on CF of milk was reported by Garg et al. (2016); milk CF decreased by 22% after applying allocation to all services and products. Furthermore, Weiler *et al*. (2014) reported that CF of milk production in Kaptumo smallholder dairy farm was 2.0 kg CO_2 eq/kg milk when only milk and meat product were considered. The CF of milk was further reduced to 1.6 kg CO_2eq/kg of milk when economic function allocation (including milk, meat, finance, manure and insurance) was applied. The current study also showed that CH_4 emission had the principal (80%) (Figure 20) contribution to the overall emission per farm. This result is lower when compared with the report of FAO & NZAGRC (2017) reported as 87.3% of the emission in the dairy farming was contributed by enteric CH_4, CO_2 and N_2O emissions in the current study accounted for the rest 3% of dairy farm emission.

CHAPTER SIX: CONCLUSIONS

The following conclusions were drawn from the result of this particular study.

6.1. Production system

In the current milk shade, young people were attracted in dairy business in both urban and peri-urban dairy production, and majority of dairy farmers attended primary or secondary school. Females were involved in dairy business even though they were dominated by males. Urban smallholder dairy farmers averagely hold a lower number of productive cross breed cows than peri-urban dairy farmers who kept more unproductive local breed cows. Peri-urban dairy farmers dominantly practised crop-livestock mixed farming and gave equal emphasis for both milk and crop production. However, urban farmers were more interested on milk production. In the current milk shade, smallholder dairy farmers kept dairy cattle for different functions. Milk, insurance and financing were the top three reasons to keep dairy cattle in urban production while peri-urban also look for draught power since they practice mixed farming. An urban dairy farm averagely produced large quantity (9260 l) of milk per year than peri-urban dairy farm of which majority of it was marketed. Almost all of dairy farmers in the current milk shade did not produce forages to feed their dairy cattle.

The major feeds identified for dairy cattle include crop residues, industrial by-products and local distillery by-product. Fed scarcity was severe during crop cultivation seasons since availability of crop residues were less. Feed preservation methods were not widely practised in both urban and peri-urban dairy production. Majority of smallholder dairy farmers were not aware of greenhouse gas emissions from cattle and their contribution to climate change. Females contributed the majority of labour in processing milk at home, manure collection from barn, milk selling and feeding while, attending of cows and selection for breeding was the major task of male farmers. Majority of dairy farmers in the milk shade either utilize manure as fertilizer and fuel or sale manure. None of peri-urban dairy farmers used manure for biogas. In addition, majority of farmers in the milk shed managed manure as solid storage system and burned for fuel; a huge proportion of manure produced was managed as solid storage system.

6.2. Carbon footprint of milk production

The carbon footprint of milk at smallholder production indicated that inclusion of multi-functions of cattle had strong impacts on the overall figure of carbon footprint. Hence, the carbon footprint of milk in urban production was reduced from 2.07 to 1.76 Kg CO_2eq/ litre while from 4.71 to 3.33 Kg CO_2eq/ litre in peri-urban dairy production. Urban dairy farms had higher emission per litre of milk than peri-urban dairy farms that is due to low milk production and large number of cattle per farm. In addition, peri-urban dairy farms emitted higher GHGs in other different multifunction. In smallholder production, enteric emission had a huge contribution to carbon footprint of milk which cows had the largest share. Emission related to feed transportation is less due to the common use of locally available transportation systems which do not consume fuel. Emission from manure management was higher in peri-urban dairy production which is related to large amount of manure production.

CHAPTER SEVEN: RECOMMENDATIONS

Based on the results of this study, the following recommendations were proposed for main stakeholders.

7.1. Smallholder dairy farmers

As indicated in the result and discussion, the major contribution of emission in dairy production was enteric fermentation. To minimize this enteric emission, the following recommendations were given.

7.1.1. Feed management

- **Selecting feeds which have relatively higher CP% and metabolizable energy**

Dairy cattle feeds which were locally available could be selected by their high metabolizable energy and crude protein percent. Feeds which have better digestible or metabolizable energy can be easily digested and converted to milk production. This increases milk production and decreases GHG emission per litre of milk. Based on these assumptions the following feeds were selected for smallholder dairy farmers.

Forage feed type	Crop- residue feed	Concentrate feed
1. Green pasture 2. Maize green forage	1. Teff straw 2. Wheat straw	1. Atella 2. Brewery grains 3. Wheat Bran

- **Forage production in peri-urban dairy production system**

It has been confirmed by this study that almost all of dairy farmers did not produce forages for dairy cattle instead they use crop residues. Improved forage species (for instance Elephant grass and alfalfa) can be planted around the main crop cultivating land or on protected grazing area in peri-urban dairy production. These improved forages have higher nutrient value and easily digestible.

- **Apply Feed preservation methods**

Hay and silage making was very rare in the milk shade. Forages that cultivated on protected private grazing land or the natural pasture can be preserved and used for scarce periods as hay or silage.

7.1.2. Herd management

Reducing unproductive animals in the herd and upgrading the genetic potentials is a key to increase productivity and reduce carbon footprint per farm and per litre of milk.

7.1.3. Manure management

Applying manure management systems especially biogas for urban farms and organic fertilizer for peri-urban farms can reduce GHG emissions from manure depositions as well as a from source of pollution in villages.

7.2. Adamitulu Agricultural Research Center

- Train smallholder dairy farmers on GHG emissions from dairy cattle management, contribution to climate change and climate-smart dairy practices. This does not only increases awareness but also have impacts on conscious and practical decisions on improved management of animals by smallholder dairy farmers. Technical training could be on:
    - Herd management: maintaining optimum /desired herd size, heat detection relating with time of insemination, dairy cow selection techniques performance recording and care of young female calves.
    - Fed management: dairy cattle feed requirement, feed selection for dairy cow, Feed treatment (urea and effective microorganism) and improved forage production.
- Improve skills of AI technicians
    - Semen handling, time of insemination, estrus synchronization and pregnancy diagnosis
- Supplying improved forage seeds for peri-urban dairy farmers and strengthening farmers to produce these improved forages at sides of cropland. In addition, identifying and releasing easily adopted and productive forage species in the existing climate conditions is vital.

7.3. Livestock and fisheries office

- Enhancing artificial insemination service with improved efficiency by improving technician skills, using fertile and genetically superior semen will help to upgrade production potentials of dairy cows hence, decrease carbon footprint of milk production.
- Train farmers on feed management of dairy animals (feed selection, feed treatment and improved forage production)
- Supporting farmers organization is important to make linkages with water, energy and mining office hence, facilitate easy adoption of manure management technologies with limited space and manure production.

Generally, CANVAS business model for urban (Figure 22) and peri-urban (Figure 23) smallholder dairy farmers are recommended.

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Appendices

Appendix 1. Questionnaire

This questionnaire is prepared to study life cycle of milk and economic analysis at smallholder dairy production in Zeway- Hawassa milk shed. We wish to assure you highest level of confidentiality about information obtained from you, and also thank you for your cooperation in assisting us with the research

Date ___________________________

Site _____________________________

Farming _____________________ (urban or peri-urban)

I. Household characteristics

1. Age and sex

Age		Sex	

2. Educational status
 1) Illiterate 2) primary 3) junior secondary 4) Senior Secondary 5) TVEC or college diploma 6) Degree
3. Total family size ________
4. Land ownership: A) Own land B) Rented Land C) Other, Specify______________
5. Size of the land ________________________

II. Herd structure and purpose of keeping dairy cattle

Herd composition	**Number**		
	Local	**Exotic**	**Cross**
Milking cows			
Dry cows			
Ox			
Bulls			
Heifers			
Calves			

Purpose of keeping dairy cattle (Give rank on the column for the given purposes)	
Purposes	**Rank**
Milk	
Meat	
Finance	
Manure	
Insurance	
Draught power	

III. Farming system

1. What type of farming system are you practising? 1) Livestock 2) mixed livestock and crop
2. What is your major agricultural farming activity? 1. Milk production 2. Crop production 3. Feed production
3. What is the major source of income for your family?
 1. Milk selling 2. Selling live animals 3. Crop selling 4. Feed selling 5. Specify______________________________

IV. Milk Production and selling

1. What is the average annual production of milk? (Fill the following table)

Average Milk yield per day per cow	Number of milking days per year	Number of cows milked per year

2. What is the amount of milk sold and consumed at home per day?

Amount of milk produced	Amount of milk consumed	Amount of milk sold	Price per liter

3. Do you always supply milk to the market? 1. Yes 2. No

4. Where do you sell milk?
   1. At farm gate 2. Transporting to hotels and café 3. To middlemen 4. Transport to local market. 4. Specify___________
5. What is the distance you travel to sell the milk______________________

V. Live animal selling

1. Do you sell live animals? 1. Yes 2. No if yes please fill the table below for the number and reason of selling of animals per year.

Reason for selling	**Type of animal (Calf, dry cow, retired ox..)**	**Number of animals sold**	**Price per head**

VI. Feeding system

1. What is the main source of feed for your dairy cattle?
   1. Grazing pasture 2. Crop residues 3. Dairy ration (concentrate) 4. Brewery products 5. Other__________________________________
2. Do you produce forages for animal feed? 1. Yes 2. No
3. Do you use fertilizers and machines for feed production? 1. Yes 2. No
4. Do you purchase forage for your cattle? 1. Yes 2. No
5. How often do you purchase animal feed?

Type of feed	**Rate of purchase (per week, day, per month, per year)**	**Price of purchase**	**Amount purchased (estimate in KG)**
Forages			
1.			
2.			
3.			
Concentrate			
1.			
2.			
3.			
Crop residues			
1.			
2.			
3.			

6. Specify the type of forage and amount produced and offered for cattle?

Type of forage	Amount produced (kg)(per season, or per year,	Estimated amount given per day per head in kg to:					
		Milking cow	Dry cow	Ox	Bull	Heifer	Calve

7. How often do you offer feeds for dairy animals (please provide the frequency of feeding different kinds of feed to herd structure) such as once a day, Or,..

Type of feed	Frequency of offering:					
	Milking cow	Dry cow	Ox	Bull	Heifer	Calve
Crop residues						
Dairy ration						
Brewery products						

8. Specify the type of crop residues and amount produced /purchased and offered for cattle

Type crop residue	Estimated amount given per day per head in kg to:					
	Milking cow	Dry cow	Ox	Bull	Heifer	Calve

9. Specify the type of concentrate feeds and amount purchased and offered for cattle

Type of concentrate feed	Estimated amount given per day per head in kg to:					
	Milking cow	Dry cow	Ox	Bull	Heifer	Calve

10. Specify the brewery product purchased and offered for cattle?

Type of brewery products	Amount purchased (kg)	Estimated amount given per day per head in kg to:					
		Milking cow	Dry cow	Ox	Bull	Heifer	Calve

11. Specify the transportation mechanism of feeds

Type of feed	Amount of feed ration (Kg)	Type of transport	Distance of transportation	Cost of transportation	Frequency of transportation per year

12. What is the source of water for the animals (choose up to 2)?
 1) On farm well 2) Piped public water supply 3) Rain catchment 4) River / stream____
 5) Other, Please Specify…………………………………………………………………………
13. How long it takes to get water for your farm? (Please express it in hour or minutes)_______________
14. Do you regularly experience a shortage of feed? A. Yes B. No
15. If yes, which season / month do you experience the most severe Shortage?

Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec

16. How do you obtain feed when experiencing a shortage of feed, please explain
 ………………………………………………………………………………………………………

VII. Crop production

Type crop	Amount of land allocated (ha)	Amount crop produced per year (kg/ha)	Average Price of the grain per kg

1. What type of land preparation and trenching do you use? 1. Animal 2. Machine 3. Both
2. Fill the following tables for animal ploughing

Type of crop cultivated	Land size (hectare)	Number of animals used for land preparation and trenching per year	Number of days animals used on field per year	Estimated hours animals work per day on field

3. What is the average rent cost of draught animals?

Cost of rent draught animal	**Period of time**

4. Fill the following tables for farm machine use

Type of crop cultivated	Land size	Frequency of machine use per year for land preparation	Time used by machine to prepare land		Frequency of machine use per year for crop harvesting	Time used by machine to harvest	
			Days	**Hours**		**Days**	**Hours**

VIII. Manure utilisation and handling systems

1. What kind of manure management system do you mostly practice? (Select only one)
1. Daily spread 2. Solid storage 3. Dry lot 4. Liquid/Slurry 5. Anaerobic digester 6. Composting 7. None
2. What is the most use of manure in your system? (Rank the top three)

Use	Rank	Duration (months)
Food crop production (fertilizer)		
Biogas generation		
Apply to fodder		
Dry dung for fuel		
As construction material		
Sale to others		

3. Do you use synthetic fertilizer for crop production? 1. Yes 2. No
4. If yes to the above questions how much fertilizer do you apply?

Type of fertilizer	Amount applied (Kg) per season or determined by the respondent	Frequency of application per year	Total cultivated Land size	Cost of fertilizer per 50 kg
Urea				
Manure				

5. If you do not prepare compost, which of the following are the most determining reasons? (Rank top 3)

Reason	Rank
Labor shortage	
Limited amount of manure	
Limited knowledge	
Time consuming	

IX. Climate change

1. Have you heard about climate change? A) Yes B) No
2. Select features that indicate climate change
   1) More frequent droughts 2) Changes in crop yields 3) Flooding 4) disease outbreaks
   5) Erratic rainfall 6) Did not notice any change
3. Do you think the events identified in the question above had an impact on your dairy farm?
   A) Yes B) No
4. As a dairy farmer, are you aware that your activities (cattle management) can contribute to climate change or reduce the impacts of climate change? A) Yes B) No
   If yes, can you tell us? ………

X. Involvement of women in CSD practice.

Please fill the responsible body in the family for the following activities

Activities	Responsible person					
	Husband	Wife	Daughter	Son	Male hired labour	Female hired labour
Manure collection						
Manure application on farm						
Feeding animals						
Silage making						
Hay making						
Feed treatment						
Feed selection						
Transporting feeds						
Select cows for insemination						
Milk selling						
Milk processing						

XI. Cost- Revenue source of the farm

1. What are the different input cost used for milk production

Input/ Materials	Quantity	Unit price	Total price (Birr)

2. What is your source of revenue from your dairy farm?

Revenue source	Quantity	Unit price	Total Revenue (Birr)

XII. Challenges and opportunities

1. What are the constraints in dairying practices? Please rank the most 5 constraints

Challenges	Rank
high cost of dairy cow and inputs	
lack of credit	
disease occurrence	
low price of milk	
shortage of feed	
Limited processing plant	
Land shortage	
Limited extension service	
Others, specify	

2. What are the opportunities to enter dairy production subsector?

Opportunities	Rank
better market access	
Extension service	
availability of veterinary service	
Access to credit	
Other, Specify	

Appendix 2. Tools for farmers group discussion

1. Gender task division in dairy production

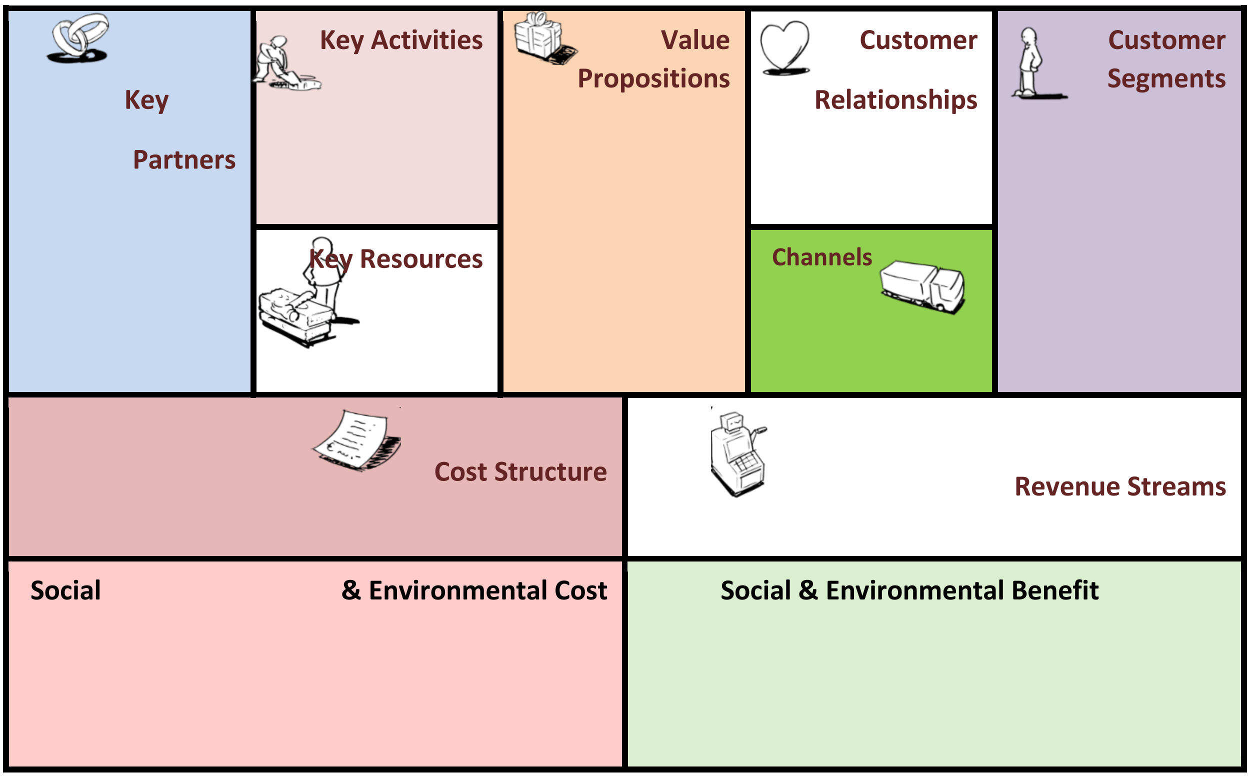
The chart is for both urban and peri urban dairy farmers (FGD).

Activities	**Responsible person**					
	Husband	Wife	Daughter	Son	Male hired labour	Female hired labour
Manure collection						
Manure application on farm						
Feeding animals						
Silage making						
Hay making						
Feed treatment						
Feed selection						
Transporting feeds						
Select cows for insemination						
Milk selling						
Milk processing						

2. Production calendar and feed availability

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Season/(dry and rainy												
Crop harvesting												
Teff												
Wheat												
Barley												
Feed availability												
Crop residues												
Teff												
Barley												
Wheat												

5. CANVAS business model



Appendix 3. Default emission factors and other values used in estimation

Variables	Values from	Remark
EF1	0.01	emission factor for N_2O emissions from N inputs, kg N_2O–N per (kg N input).
Frac (GASF)	0.1	Fraction of synthetic fertiliser N that volatilises as NH_3 and NO_x, kg N volatilised per (kg of N applied)
Frac (GASM)	0.2	fraction of Organic fertiliser N that volatilises as NH_3 and NO_x, kg N volatilised per (kg of N applied)
EF4	0.01	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–N volatilised)]
EF5	0.3	emission factor for N_2O emissions from N leaching and runoff, kg N_2O–N (kg N leached and runoff)
Frac(leach)	0.0075	fraction of all N added to/mineralised in managed that is lost through leaching and runoff, kg N per (kg of N additions)
Ym	0.065	Methane conversion factor, percent of gross energy in feed converted to methane
B_o	0.1	maximum methane producing capacity for manure produced by livestock category
(UE • GE)	0.04GE	urinary energy expressed as a fraction of gross energy
ASH	0.08	Ash content of cattle manure
DE%	50%	The digestability of cattle feed on low quallity forage
MCF(S,k)	an aerobic digester = 10% dry and burned for fuel = 10% composting =1% daily spread= 0.5% solid storage= 4%	MCF by average annual temperature 15-25: methane conversion factors for each manure management system *S* by climate region *k*, %
MS%	an aerobic digester = 4.55% dry and burned for fuel = 7.28% composting =0.67% daily spread= 31.76% solid storage= 55.74%	fraction of cattle manure handled using manure management system.
FracGasMS	Daily spread=7% An aerobic digester = 35% Composting = Not available Burned for fuel= Not available Solid storage=45%	percent of managed manure nitrogen for livestock category *T* that volatilises as NH_3 and NO_x in the manure management system *S*, %
FracLeachMS	Solid storage =10%	percent of managed manure nitrogen losses for livestock category *T* due to runoff and leaching during solid and liquid storage of manure
EF5	0.0075	emission factor for N_2O emissions from nitrogen leaching and runoff, kg N_2O-N/kg N leached and runoff
Manure produ-ction DM%/head	0.8%	Lekasi et al., 2001
Manure nitrogen content	1.4%	Lekasi et al., 2001

Appendix 4. Images during the study

Image 1. First stakeholder meeting at Adammi Tulu and Shashemene

Figure 2. FGD applying participatory tool.

Image 3. Rainfall distribution, crop production and harvesting calendar chart prepared by smaller holder farmers

Image 4. Gender task chart in dairy production produced by urban and peri urban farmers

Image 5 CANVAS business model prepared by smallholder farmers at Adamitulu and Shashemene

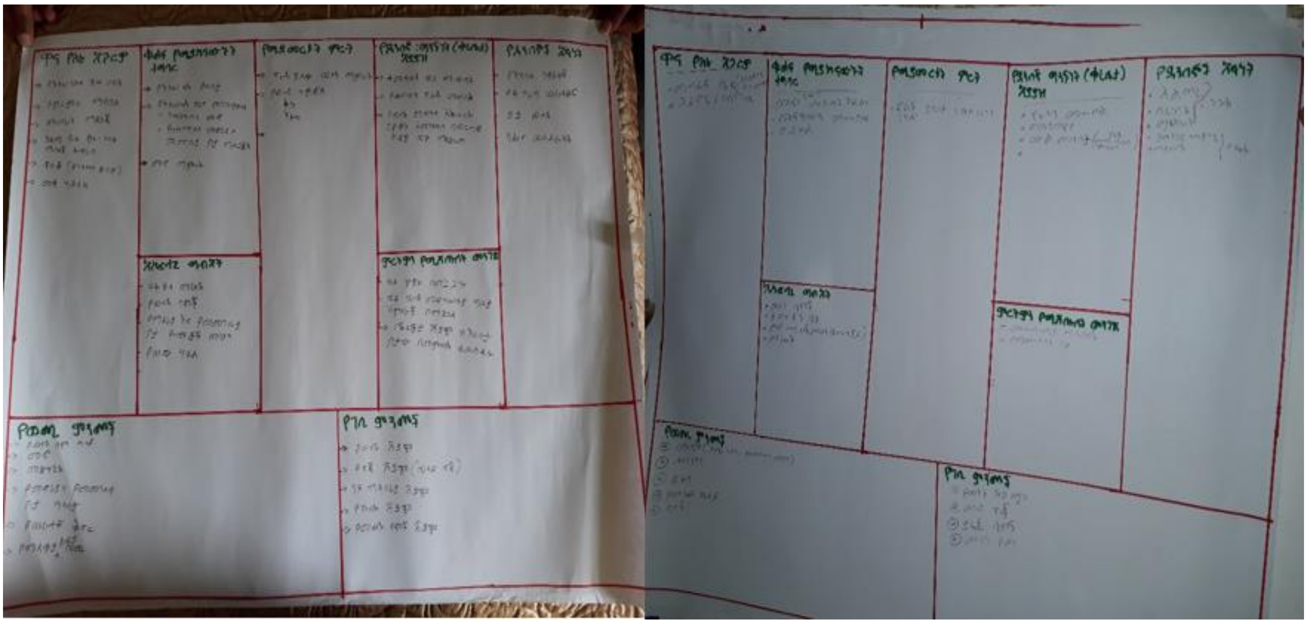


Image 6. field data collection

Image 8. Final stake holder meeting at Adami Tulu

Image 9. Final stakeholder meeting at Shashemene.