Final report

TAAF-0071 Enhancing climate change outcomes in development programs in Uganda:

Increasing resilience and lowering emissions in the dairy value chain

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EXECUTIVE SUMMARY

This report responds to the tender: 'Enhancing climate change outcomes in development programmes in Uganda', issued 24 October 2016 (CDKN Project Reference: TAAF-0071).

The tender specified two research gaps to be addressed:

Q1) Identify successful Ugandan examples of scalable and sustainable climate smart interventions that can be used to increase resilience and lower emissions in the dairy value chain. Focus on three key stages across the value chain.

Q2) What are the economic opportunities for entrepreneurs and companies to invest in climate change adaptation to enhance the resilience of Uganda's livestock value chain, and are there trade-offs in these opportunities?

The research was carried out by a consortium of organisations:

- SNV/Netherlands Development Organisation: SNV was the lead in this applied research and implements the TIDE project in southwest Uganda that served as an entry point (i.e. making use of existing contacts and connections). TIDE is a 4-year project (2015-2019), funded by the Embassy of the Kingdom of The Netherlands, focusing on increasing productivity and quality of dairy, as well as on strengthening value chain governance and dynamics (lead for the research: Paul Kimbugwe; overall responsible: Rinus van Klinken).
- Wageningen University of Research: is partnering with SNV on the TIDE project, and provided much of the literature insights and technical knowledge on mitigation and adaptation processes for this report (Joep van Mierlo and Marion de Vries).
- National Agricultural Research Organisation (NARO): is a partner on the TIDE project and is mandated to provide applied agricultural research. NARO undertook most of data collection and analysis for this research report (David Balikowa).
- Mbarara University of Science and Technology (MUST): is a local university in southwest Uganda, and partner in the TIDE project. MUST contributed to the analysis and collection of data for this report (Ronald Twongyirwe).
- International Institute for Sustainable Development (IISD): is an international knowledge institute. IISD provided an international perspective and contributed methodological and analytical insights to this assignment (Julie Dekens).

The research focused on fully addressing question 1 and contributing to question 2 in the context of the dairy value chain. Although the research has a national outlook, most of the field data were collected in the southwest region of Uganda. This creates a certain bias in results, particularly in the production segment of the value chain. For the other segments of the dairy value chain - input supply (with a particular interest in fodder and conserved feed production), bulking and transportation (for both the formal and informal sector), and processing and value addition - the findings are more generally applicable. For these latter segments, both regional and national actors were brought into the data collection process, and involved in analysis.

Methodology

To arrive at the scalable and sustainable climate smart interventions (or 'best practices'), a combination of methodologies was used (documented in chapter 2). An initial longlist of possible adaptation- and mitigation-related behaviours and practises along the dairy value chain was collated from various sources, including a **literature review** and **interviews** with key informants. Based on this longlist, **focus group** discussions were convened with stakeholders, grouped along the different segments of the dairy value chain. Stakeholders were asked about their awareness of climate change, the available possible responses and the barriers to further uptake of suitable practices. The findings from these discussions are detailed in chapter 3. As the focus group discussions were general, and could not go into depth, the research team carried out **case studies**, to detail the key practices that were mentioned by the stakeholders and were deemed justified by experts. The results of this step are described in chapter 4.

Two further methodologies were used to gather expert input and analysis throughout the process. **Consortium** meetings were convened to bring the research partners together in physical and on-line meetings, and a **reference group** meeting brought together key experts operating at national level. During the analytical discussions it became clear that the list of suitable practices as identified by the stakeholders did not differ substantially from those found in the literature. Further, it was realised that one of the key barriers to making these practises truly scalable is the fact that none of the recommended best practices, in isolation, will generate results for stakeholders with regard to resilience, adaptation and mitigation. Instead, it is often only by linking some of the practices together that the desired impact can be achieved. The key contribution from this research to the climate debate in the dairy value chain in Uganda is therefore the characterisation of two key integrated practices, which are documented in chapter 5, and summarised in the findings below.

For addressing the second question (economic opportunities), the same methodology and process was used. During the abovementioned focus group discussions, organised by segment, participants were asked what private sector opportunities they saw in the responses currently available within the market. Findings are described in chapter 6, and closely tie in with the integrated practices, mentioned above.

Findings

Although the aim of the research was to identify suitable practices in the different segments of the value chain, there was unanimity between all actors that climate impacts are the most pronounced at the production segment of the dairy value chain. Climate change events at production level cascade through the entire value chain because the other segments all depend on the supply of sufficient good quality milk. Stakeholders throughout the value chain identified climate smart "best" practices as those that enhance or maintain productivity during an adverse climate event, or those that help farmers earn extra income.

A total of eight such practices were identified during the study:

1. **Rainwater harvesting and storage**: as availability of water is crucial to increasing productivity and resilience, a better and broader application of water harvesting and storage (as well as distribution) technologies is an important practice.

2. **Planting of improved pastures/fodder crops plus forage conservation**: this practice increases resilience, and as it makes a major contribution to reducing the large deficit in milk production in the dry season (as compared to the wet season), it also benefits the other segments of the dairy value chain.
3. **Feeding of crop residues and agro-industrial by-products and their conservation**: similar to the practice described above, its effects are mainly felt in the dry season with benefits cascading throughout the chain.
4. **Crossbreeding of indigenous cattle with appropriate exotic dairy breeds**: crossbreeds combine the high milk yields from exotics with tolerance to harsh climatic conditions of the indigenous breeds.
5. **Generation of Renewable Energy (biogas) from manure and water harvesting**: using manure to generate biogas can reduce GHG emissions, although water availability is a key ingredient for making this work.
6. **Use of solar energy to operate milk coolers**: solar power can address the problems of lack of grid power in rural areas (and are therefore a good alternative to diesel generators), and can also contribute to increasing the quantity and quality of milk across the supply chain if on-farm storage becomes feasible (increasing the utility of evening milking).
7. **Innovative Agricultural Insurance and Financial Services**: the use of smartphones can make it easier for dairy farmers to keep farm records, which are often a key requirement to access financial services for dairy farmers, including the application of relevant insurance products.
8. **Integration of climate services in dairy value chain interventions**: although these services are still being piloted, enhanced dissemination of increasingly available climate-relevant information can contribute to improved implementation of the various practices, listed above.

One of the findings of this research is that the individual practices, as described above, have limitations in terms of adoption (change in practice) and impact, and may not fully deliver the desired results in isolation. Most of the practices are already applied by farmers, though not yet at scale. This study therefore recommends a combination of key practices that offer the best opportunity for the stakeholders to adopt and contribute to climate change adaptation and mitigation, and maximize their benefits.

The two key combinations of practices that are recommended are:

- **Planting of improved pastures, combined with forage conservation, improving indigenous breeds and water harvesting**: combining these practices maximises their benefits, and in some cases even enables their realisation. Providing supplementary feeding to dairy animals, but without simultaneously increasing availability of water, or alternatively providing the feed (and water) to animals with low genetic potential, increases production costs and may not generate the anticipated benefits (economic, resilience, greenhouse gas emissions).
- **Improving the efficiency of the value chain**: this can include a number of individual practices, as listed above, and mainly addresses the pre-condition under which they can be effective. By creating direct durable links between dairy producers and processors, investments across the chain (but particularly at production level) are encouraged and become feasible.

The following economic opportunities for investment by the private sector within the dairy value chain were identified:

- Commercialization of forage production, conservation and marketing;
- Improving of dairy breeds through cross-breeding;
- Rainwater harvesting, storage and distribution;
- Innovative Agricultural Insurance and Financial Services for Milk Producers.

Not by co-incidence, these economic opportunities fall squarely within the identified combinations of practices. After all, it is these combinations of practices that offer the biggest potential demand from users, have the potential to benefit many stakeholders in the value chain and offer maximum benefits. They also contribute to overcoming the barriers to adoption of the identified best practices.

The research also examined whether national policies allow for, or encourage the identified practices. It appears that there are two policy windows, which can be utilised to facilitate the implementation of the recommendations of this research:

(1) The current lack of a national dairy sector policy presents an opportunity for developing a climate responsive policy for the dairy industry;

(2) There is a need for policy reviews on agricultural insurance, i.e. to make insurance schemes more accessible and useful to dairy farmers and other stakeholders in the chain.

Limitations

As described in the methodology section, this research does not present state of the art information on suitable practices for climate smart dairy farming, but rather presents an overview of current practices within the sector, based on stakeholders' understanding and appreciation of the context. As a result, there is a much stronger focus on adaptation, rather than mitigation, as resilience is of direct relevance to stakeholders.

Another caveat applies to the described impacts of implementing the proposed practices. There is an important difference between absolute greenhouse gas (GHG) emissions (i.e. total CO_2-eq.) and GHG emission intensity (i.e. kg CO_2-eq. per unit of output). Most of the claims about reduced GHG emissions in the report are about emission intensity. Hence, in some of the described cases, absolute emissions will increase. An example is fodder conservation: due to mechanization, the use of fossil fuel and CO_2 emissions will increase, hence, absolute GHG emissions will increase. Due to the improved productivity of cattle, one may expect increased emissions from fossil fuel use will be compensated in terms of emission intensity. The same accounts for compound feed, which generally has a high carbon footprint that increases absolute emissions but may reduce emission intensities. Further research will be required to validate whether overall emissions will indeed occur as a consequence of the proposed interventions.

ACRONYMS/ ABBREVIATIONS

aBi Trust,	Agri-Business Initiative Trust
AI	Artificial Insemination
ASARECA	Association for Strengthening Agricultural Research in Eastern & Central Africa
CDI	Centre for Development Innovation
CDKN	Climate and Development Knowledge Network
CH4	Methane
CIAT	International Centre for Tropical Agriculture
CSA	Climate Smart Agriculture
CO_2	Carbon dioxide
DDA	Dairy Development Authority
DFID,	Department for International Development
EADD	East Africa Dairy Development
EKN	Embassy of the Kingdom of Netherlands
FAO	Food and Agricultural Organisation of the United Nations
FGD	Focus Group Discussion
FPCM	Fat and Protein Corrected Milk
GHG	Green House Gases
GIZ,	Gesellschaft für Internationale Zusammenarbeit
GoU	Government of Uganda
IISD	International Institute for Sustainable Development, Switzerland
ISSD,	Integrated Seed Sector Development
LCA	Life Cycle Assessment
MSIP	Multi-Stakeholder Innovation Platform
MUST	Mbarara University of Science and Technology
NaLIRRI	National Livestock Resources Research Institute
NAMAs	National Adaptation and Mitigation Action Plans
NAPS	National Adaptation plans for Agriculture
NARO	National Agricultural Research Organisation
N_2O	Nitrous Oxide
OWC	Operation Wealth Creation
SALL	Sameer Agricultural and Livestock Limited
SNV	The Netherlands Development Organisation
SSA	Sub-Saharan Africa
SW	South Western
TIDE	The Inclusive Dairy Enterprise
UCCCU	Uganda Crane Creameries Cooperative Union
USAID	United States Agency for International Development
VCs	Value Chains
WUR	Wageningen University of Research

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1. INTRODUCTION

1.1 Background

The livestock sector in Uganda contributes 18 % to the agricultural GDP, with dairy thought to be contributing 80% of the livestock sector GDP. The dairy sector plays a very important role in the lives of many Ugandans, as a source of food, income and employment (UBOS, 2017). The sector employs millions of people along the value chain.

The economy and livelihood of many Ugandans is tightly bound to climate. Over 80% of the population is rural and dependent on rain-fed agriculture. This dependency on rain fed production means that revenues from the dairy value chain are susceptible to impacts of climate variability. Climate variability affects the availability and quality of pastures and water, as well as disease prevalence, intensity of heat load and discomfort caused by temperature and humidity. These changes impact directly on feed intake, reproduction and growth of the animals (MAAIF and MWE, 2016).

Climate change is one of the greatest global challenges today. Uganda, like many countries, is already witnessing first-hand the devastating effects of climate change. Prolonged droughts and unpredictable weather patterns are some of the evident changes that are impacting the predominantly agricultural populace. Adapting to the inevitable effects of climate change and facilitating the development of alternative solutions to help Ugandans increase their resilience to the negative consequences of climate change has never been more urgent (MAAIF, 2017).

Climate smart agriculture (CSA) is an approach to developing the technical, policy and investment conditions that minimise trade-offs between food security and environmental services. The Food and Agricultural Organisation (FAO) defines CSA as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes greenhouse gas emissions (GHGs; mitigation) where possible, and enhances achievement of national food security and development goals" (FAO, 2013).

CSA has 3 main pillars:

1. Increasing climate change resilience (adaptation),
2. Mitigation of greenhouse gas emissions, and
3. Enhancing productivity and income.

In this research, emphasis was on the first two pillars.

Objective of the assignment

In 2016, the Climate and Development Knowledge Network (CDKN) convened an Action Lab, hosted by the Embassy of the Netherlands in Kampala, the Netherlands Ministry of Foreign Affairs and CDKN. The principal aim was to deepen the understanding of the potential risks from climate change, and the adaptation and mitigation opportunities, for i) Ugandan livestock and dairy value chains, and for ii) enhancing the resilience of climate migrants in Uganda. At the action lab, research gaps were identified, and subsequently formulated into a tender called: 'Enhancing climate change outcomes in development programmes in Uganda', issued 24 October 2016 (CDKN Project Reference: TAAF-0071).

The tender specified two research gaps:

> Q1) Identify successful Ugandan examples of scalable and sustainable climate smart interventions that can be used to increase resilience and lower emissions in the dairy value chain. Focus on three key stages across the value chain.
>
> Q2) What are the economic opportunities for entrepreneurs and companies to invest in climate change adaptation to enhance the resilience of Uganda's livestock value chain, and are there trade-offs in these opportunities?

The research reflected in this report addresses question 1 fully (examples of interventions). Question 2 (economic opportunities) is also covered, but rather than examining this for the entire livestock value chain (as the question suggests), this report only deals with economic opportunities in the dairy value chain.

1.2 The Dairy Value Chain

The dairy value chain is characterized by the following segments (see figure 1, which is based on the southwest region of Uganda, but is applicable for most other parts as well):

1. Input supplies
2. Milk production
3. Milk collection, bulking and transport
4. Dairy processing
5. Distribution and marketing (consumption).

Each of these segments is described in detail in this section, with the exception of the consumption phase, which falls outside the scope of this research (see also chapter 2).

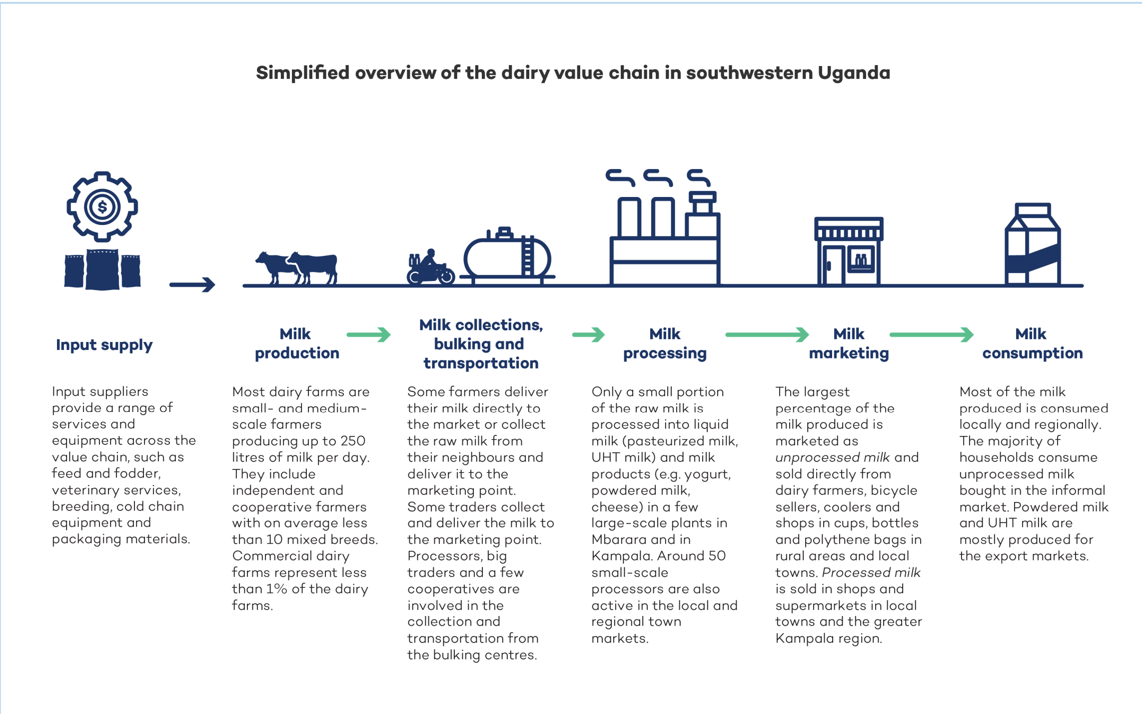

Figure 1: Simplified overview of the dairy value chain in the southwest region of Uganda (source: Authors)

Milk production systems

The southwest dairy region broadly has three milk production systems:

- **The pastoral system** has farms with greater than 50 indigenous cattle grazing on coarse pasture throughout the year. They are milked twice a day but do not get any supplementary feeding.
- **The peri -urban small-scale mixed crop and livestock farms system** keep mixed dairy cattle breeds with an average of less than 10 cows.
- **The commercial dairy farms** (above 200 acres in size) keep 20 to 100 pure and crossbred dairy cows largely on planted pastures supplemented with grain by-products and oilseed cakes.

Milk production at the farm level depends on availability of support services such as feed and fodder suppliers, veterinary and animal health service providers, extension services (both private and government) and animal breeding and genetic improvement services.

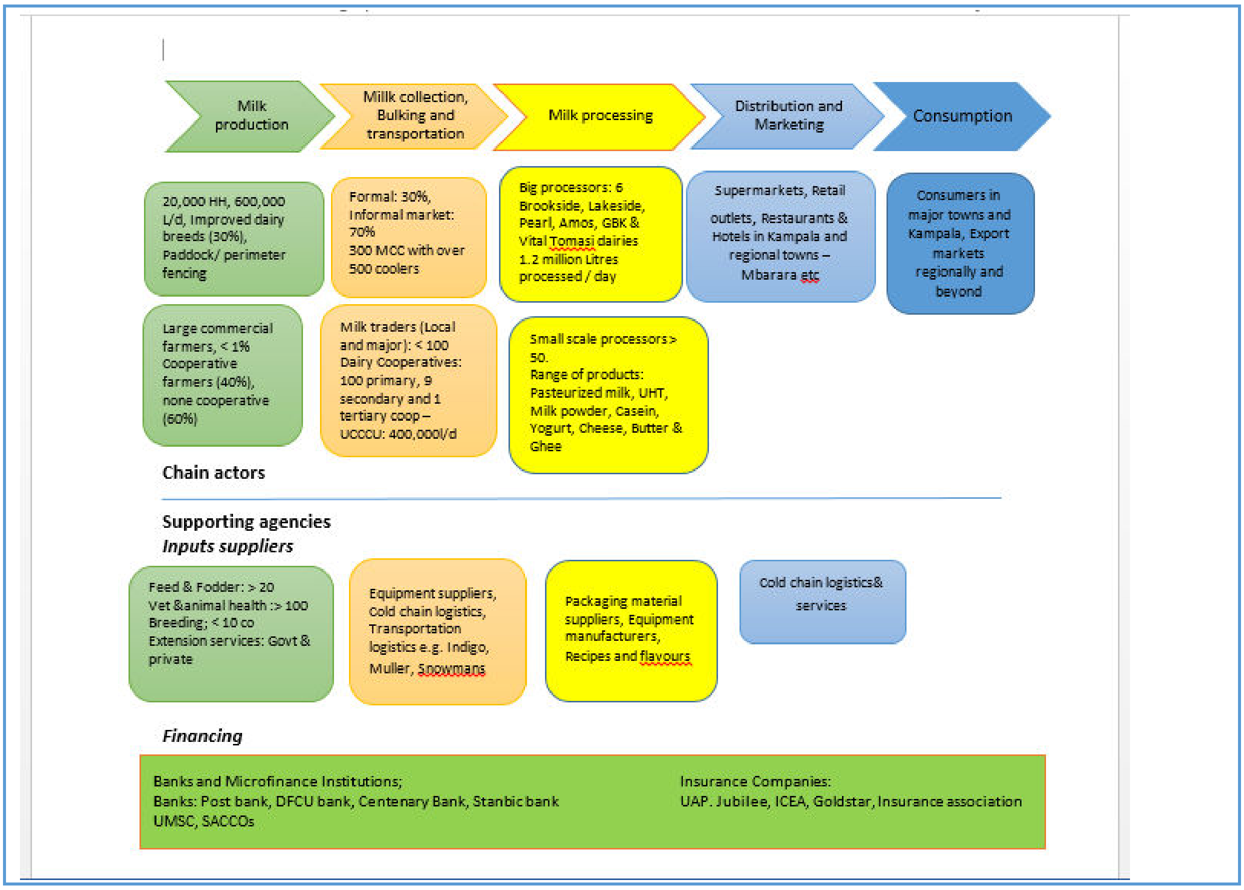

Figure 2: Dairy value chain actors in the southwest region of Uganda (source: Authors)

Milk collection, bulking and transport

Milk collection, bulking and transportation link dairy farms (cooperatives and commercial dairy farmers) to processing plants and the informal markets in local towns in the southwest region and Kampala. Milk in the southwest region is marketed both formally and informally, with the informal market commanding the largest market share (70 %).

A chain of milk collection infrastructure exists in the region and is owned by dairy cooperatives, processors and milk traders. According to a milk cooler census conducted by TIDE in 2016, there were 308 Milk Collection Centres (MCCs) with 446 Milk coolers in the six districts around Mbarara. Milk coolers are primarily owned by individuals (46 %) and farmers (41 %) followed by processors (12 %), with government owning less than 1%.

Figure 3 shows the volumes of milk collected by the MCCs in the different seasons compared to their installed capacities. While the total amount of milk collected in the dry season (in 2016) was less than half the total milk cooler capacity, during the wet season the milk supply surpassed that capacity.

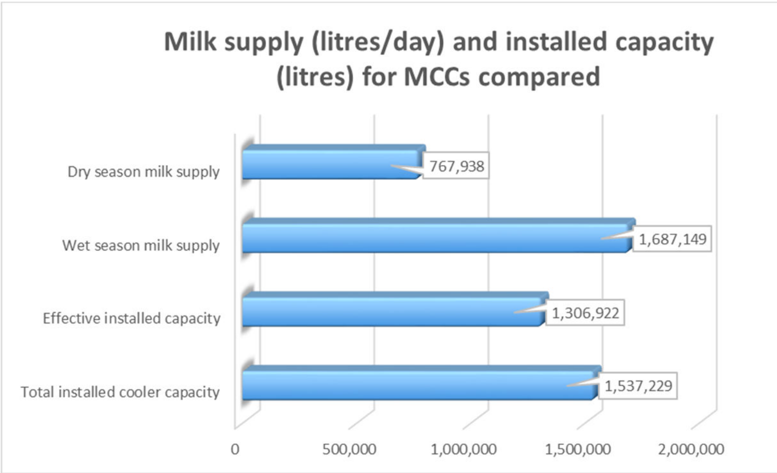

Figure 3: Milk cooler census by TIDE, 2016

Dairy Processing

As of 2016, the southwest region had a total of five dairy plants processing its raw milk. Four of these plants are located in Mbarara and one (Brookside) in Kampala. These plants rely on cost-efficient access to products and services supplied by industries, from packaging materials, to spare parts and equipment manufacturers for dairy processing plants. There are also a host of small-scale processors that are adding value to their milk, by producing other milk products like drinking yogurt for the local and regional town markets.

Figure 4 shows the trend, for the last 5 years, in combined processing capacity of the different processing plants compared to the major dairy processor, Sameer Agricultural and Livestock Limited (SALL) – Brookside, based in Kampala. It should be noted that whereas processing capacity has drastically increased, capacity utilization of the various processing plants is low overall.

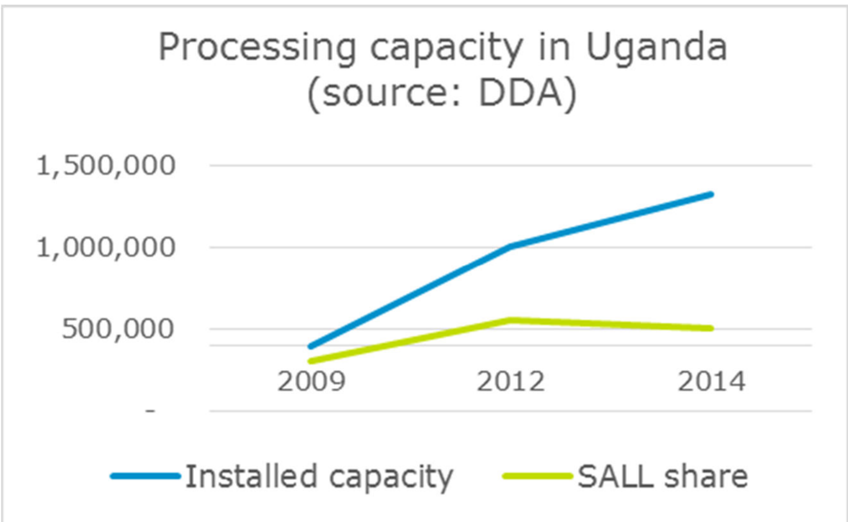

Figure 4: Processing capacity in Uganda

1.3 Climate Change Adaptation.

Downscaled projections for climate change at the country level (modified after USAID, 2015) are summarised in table 1.

Table 1: Projections for climate change at the country level

Parameter	Trends	Unit	Years 2030	Years 2050	Source
Change in:					
Mean annual temperature	Increase	Median °C	0.9-1.0[a]	1.4-1.8[a]	CCKP, 2017[c]
No. of hot days per year	Increase	%	10-27[b]	16-43[b]	McSweeney et al., 2010a, b
Precipitation	Increase	mm/day	0.2		Alders et al., 2013
Extreme events	Increase	Drought/floods	Yes	Yes	IPCC, 2013

[a] Values represent multi-model ensemble medians of RCP4.5 (first value) and RCP8.5 (second value) scenario estimates
b UNDP projections (McSweeney et al., 2010a, b) are based on SRES scenarios.
C World Bank Climate Change Knowledge Portal (data from CMIP5 distribution; Taylor et al. 2012),

Some of the key elements of the table:

a. Increase in mean annual **temperature** by 0.9-1.0°C in 2030 and 1.4-1.8°C in 2050, with greatest increases projected for the months June through September (CCKP; ensemble medians of RCP4.5 and RCP8.5);
b. Increases in the **frequency of hot days and nights**. Projections indicate 10-27% increase of "hot" days by the 2030s and 16-43% by 2060s (McSweeney et al., 2010a, b; based on SRES scenarios).
c. **Average annual rainfall** could either increase or decrease, as there is a large uncertainty in projections of average annual rainfall. Precipitation is projected to increase according to most climate models (MAAIF and MWE, 2016). Towards 2030, the median ensemble runs for RCP4.5 and 8.5 indicate an average annual rainfall increase of 0.2 mm/day (Alder et al, 2013).
d. Change in **timing of precipitation**, with some months projected to decrease in rainfall, and others to increase. There are indications that there may be a decrease in precipitation in May and June, and an increase during December, January, and February (MAAIF and MWE, 2016). Changes in the scale of the rainfall probability distribution towards 2050 indicate that **floods and droughts** may become more frequent in the future (IPCC, 2013).
e. Increase in the number of days of **extreme and heavy precipitation**, as well as the **amount of rainfall in heavy events**. Greatest increases in amount of rainfall per event are projected to occur in the rainy seasons (McSweeney et al., 2010a, b).
f. Climate change affects livestock production in multiple ways, both directly and indirectly. According to FAO (2016), the most important impacts are experienced in animal productivity, yields of forages and feed crops, animal health and biodiversity (Table 2).

Table 2: Pathways of impacts of climate change on livestock (FAO, 2016)

	Animals	Forages and feed crops	Labour force and capital
Variability in rainfall	- Shortages in drinking and servicing water - Diseases . Increased pathogens, parasites and vectors . Changed distribution and transmission . New diseases	- Decreased yields - Decreased forage quality - Changes in pasture composition (species, communities) . Changes in production system (e.g. from mixed crop-livestock to rangelands)	- Altered human health and resource allocation to livestock - Decreased productivity - Migrations - Conflicts
Temperature	- Heat stress . Decreased feed intake and livestock yields . Decreased conception rates . Altered metabolism and increased mortality - Disease . distribution and transmission through pathogens, parasites and vectors . Decreased resistance of livestock . New diseases - Domestic biodiversity losses	- Decreased yields - Decreased forage quality - Change in pasture composition	
CO_2 in the atmosphere		- Partial stomata closure and reduced transpiration - Change in pasture composition	

To reduce the impacts of climate change requires a reduction in the **vulnerability** and increase in the **resilience** of dairy systems. Resilience is the capacity of systems, communities, households or individuals to prevent, mitigate, or cope with risk, and recover from shocks (FAO, 2016) as depicted in Figure 5.

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Figure 5: Vulnerability and resilience. Source: Gitz and Meybeck (2012)

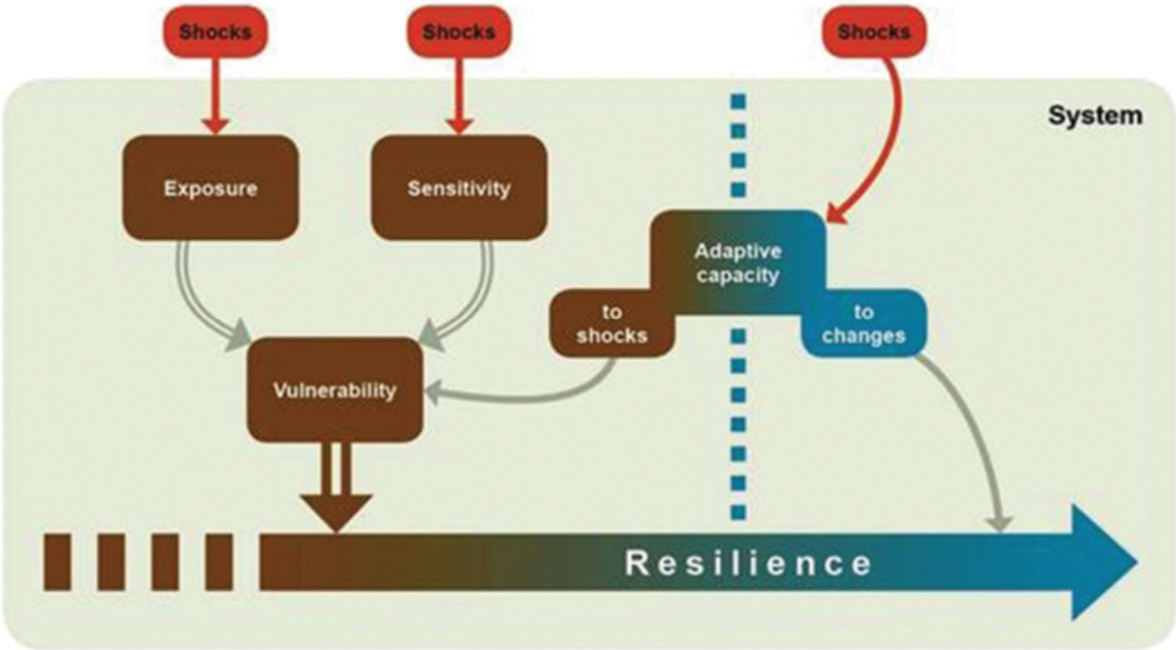

Figure 5 indicates that resilience can be contextualized in two dimensions: vulnerability of the dairy system to exogenous stress; and its capacity to recover from shocks and to adapt to changes over time. Vulnerability, in turn, depends on the extent to which the system is exposed to shocks (for example, due to the location of the herd), and the sensitivity of the system to these shocks (e.g. vaccinated, versus non-vaccinated animals). Sensitivity of animals to stress is a fundamentally genetic attribute associated with species and breed differences in physiological and behavioural responses to stress.

Extrinsic factors that moderate sensitivity, vulnerability and resilience in livestock of dairy production systems are associated with management. These include access to adequate water, good nutrition, health/veterinary services and physical protection from exposure to environmental stress.

Climate Smart adaptation options

There are three ways to build resilience (FAO, 2013):

1. Reduce exposure;
2. Reduce the sensitivity of systems to shocks (e.g. using drought-resistant varieties or keeping adequate stocks of hay);
3. Increase adaptive capacity.

Options to adapt to climate change and variability are closely linked to the biophysical, economic and socio-political aspects of an ecosystem for livestock production. The biophysical aspects involve for example, the innate capacity of the animal, as well as their feed and water resource base, to withstand climate shocks. The other aspects are primarily individual or collective decisions people make to enable them to contain risks in livestock production. These include exploitation of animal and forage diversity through selection for the best animal and forage species/cultivar for the production environment. Interventions that target intrinsic attributes of the animal include choice of animal species and breeds that are tolerant to heat, disease and water stress (Table 3). Many local livestock breeds, including the Ankole cattle, are already well adapted to high temperatures and harsh environments, through natural selection.

Table 3: Climate change adaptation options in the livestock sector (FAO, 2016a)

Animals	Forage and feed crops	Labour force and capital
-Water management (e.g. boreholes) -Breed resistance to drought, heat and harsh environments -Shifts in species, breeds and/ or production system (e.g. small ruminants, poultry) -Disease control and animal health -Cooling (indoor systems) or provide shade (e.g. trees)	-Irrigation -Purchase feed, supplementation -Breed feed crops and forages for water use efficiency and for resistance to drought, salinity and water logging -Grazing management -Changes in cropping calendar -Agro-forestry -Increase mobility for resources	-On- and off-farm diversification -Insurances -Reconversion (in the context of national/regional production zoning) -Institutional changes (e.g. trade, conflict resolution, income stabilization programmes

A significant number of interventions for climate change adaptation and mitigation target the animal indirectly. This includes feeding and feeding management; provision of clean water and using water to cool the animal during periods of temperature extremes; breeding for stress tolerance and productivity in forages; conservation of feed and water; application of water efficient technologies; grazing management and strategic supplementary feeds and irrigation in fodder production (Table 3).

Interventions that are used to enhance resilience have short, medium and long-term time frames and geographical scopes of effectiveness. While irrigation of feed crops and grasslands and purchasing feed are immediate farm-level coping mechanisms for short-term adaptation to climate change, there exist long-term options such as breeding feed crops and forages for water use efficiency, resistance to drought, salinity and water logging. More systemic, longer-term adaptation options include grassland restoration or diversification in composition; agro-forestry with fodder trees and legume shrubs to provide alternate feed resources, shade and water retention; or animal and feed mobility. In grazing production systems, these long-term adaptation strategies address the variability in availability of already scarce feed resources while providing other types of environmental services, such as mitigation of greenhouse gas emissions.

Climate change impacts beyond the production level

Climate change Impacts on production directly translate into economic impacts at farm, community and national levels through a range of different pathways that affect agricultural incomes, food market access, prices and trade, and investment patterns. At farm level, farmers can be compelled to sell productive capital, such as cattle, to absorb income shocks. Climate impacts can reduce the capacity of farmers to invest in and access welfare services like health and education. At national level, the impacts can trigger an increase in agricultural commodities' prices (food and feed), which impact the economic and social status of the whole population. Climatic risks can also hinder agricultural development by discouraging investments.

According to a study by FAO (2016) the impacts of climate/weather shocks on Ugandan household welfare are limited due to the effects of the socio-demographic and wealth situation in Uganda. This means households are able to put in place effective *ex-ante* and/*or ex-post* coping measures, such as income and consumption smoothing. Income smoothing is used to influence the decisions concerning production, employment and the diversification of the economic activities. Consumption smoothing relates to the decisions regarding borrowing and saving, selling or buying non-financial assets, modifying the labour supply and making use of formal/informal insurance mechanisms.

1.4 Climate Change Mitigation

Globally, livestock is responsible for 14.5% of the total anthropogenic greenhouse gas emissions (7.1 gigatonnes of CO_2-eq. per year), of which beef and milk production represent approximately 65% (Gerber et al., 2013). The most important GHG emissions from cattle production are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In the global dairy sector, enteric fermentation is the most significant source of GHG emissions, contributing 47% of emissions, followed by manure storage and application (26%), and feed production and processing (19%; incl. land use change; Opio et al., 2013). Energy use in the dairy sector contributes less than 2% of GHG emissions.

GHG emissions can be expressed as absolute (total) emissions or emission intensities. Global demand for dairy will continue to grow strongly (as well as in Uganda), and reduction in emission intensities is therefore important to avoid significant increases in total GHG emissions from the sector. A common way to express emission intensities from dairy production is in kg CO_2-equivalents per kg milk or FPCM (fat and protein corrected milk), and per kg live weight or carcass weight.

Worldwide, emission intensities per kg of milk range between 1.6 and 9.0 kg CO2-eq. among different regions (Opio et al., 2013). Generally, higher emissions intensities are found in systems with a lower productivity. In these systems, poor animal feeding and nutrition, genetics, animal health care, and animal husbandry cause higher emission intensities at the animal and the herd level.

Using the Life Cycle Assessment (LCA), Opio et al. (2013) showed that globally, Sub-Saharan Africa (SSA) had the highest GHG emission intensity per cow for milk and third-highest emission intensity for beef. In SSA, however, cattle often provide various other products and services besides edible products, such as fertiliser, traction, capital asset, insurance, dowry, or status. When such other functions of cattle are acknowledged in LCA analyses, carbon footprint estimates of smallholder milk production were shown to be comparable to those of intensive milk production (Weiler et al. 2014), i.e. 2.0 kg CO_2-e per kg milk in the case of food allocation, 1.6 kg CO_2-e in the case of economic function allocation, and 1.1 kg CO_2-e in the case of livelihood allocation. Therefore the functional unit used in LCA may influence the magnitude and hence the choice of mitigation options. This explains why it is important to evaluate the multi-functionality of keeping cattle in the assessment of GHG emissions and mitigation options. As milk demand is increasing and driving more dairy farms in Uganda to intensify, the use of emission intensities based on marketable products is justifiable, depending on the aim of the assessment.

According to Opio et al. (2013), differences in emission intensities are driven by a combination of factors, including the following:

1. At animal level, emission intensity is influenced by (i) digestibility, quality and composition of the feed ration (influencing enteric methane emissions and emissions from manure), and (ii) improved genetics and animal health, which contribute to better conversion of feed into animal products;
2. At herd level, emission intensity is influenced by feed quality combined with genetics, animal health, reproduction strategies (replacement, age at first calving) reducing the relative number of unproductive animals in the herd and thus emissions per unit of product generated at herd level;
3. Land-use change, i.e. pasture and feed crop expansion, is a major driver of emissions. Feed originating from areas where land use change takes place has higher emission intensities;
4. Manure management practices influence the release of methane and nitrous oxide.

Opio et al., (2013) suggest the following areas with mitigation potential:

- Improving feeding practices and digestibility of diets;
- Improving yields through genetics, feeding practices and animal health, and overall management;
- Reducing land-use change arising from feed crop cultivation and pasture expansion;
- Improving manure management – reducing the use of uncovered liquid manure management systems (MMSs), particularly in dairy systems;
- Improving the efficiency of feed.

It should be noted, however, that mitigation and adaptation in climate change related to agriculture in developing countries is too often simplified to one commodity (Weiler et al., 2014). This is a too simplified a picture, certainly in the African situation, where livestock is always part of an integrated socio/cultural-economic system.

2. METHODOLOGY.

2.1 Technical Approach and Scope

The investigation was based on the following research questions: (1) *to identify successful Ugandan examples of scalable and sustainable climate smart interventions that can be used to increase climate change resilience and lower emissions in the dairy value chain; and (2) to identify the economic opportunities for entrepreneurs and companies to invest in climate change adaptation to enhance the resilience of Uganda's dairy value chain, including any trade-offs in these opportunities.*

The investigation focused on four segments of the value chain: 1) input supply; 2) production; 3) bulking and transportation; and 4) processing. For each value chain segment, best practices are identified based on their contribution to climate change adaptation and mitigation.

> **Best practices** were defined as technologies or practices, supporting climate change adaptation and or mitigation, which are currently being applied or piloted at the national level or in southwest Uganda. These practices are also perceived as such by the value chain actors. They can also be practices related to policy interventions, institutional arrangements and information management among others.

The following attributes were used to evaluate potential best practices:

i. Contribute to reduced vulnerability of dairy value chains to climate change (adaptation).
ii. Contribute to mitigation of GHG emissions from dairy value chains.
iii. Socially or culturally appropriate and acceptable.
iv. Affordable to target users, economically viable and beneficial (cost effective).
v. Potential for replication and dissemination to different geographical areas, value chain segments and actors.
vi. Potential for commercialization (existence of viable market demand and investor interest).
vii. Does not add additional burden to women's workload.
viii. Empowers women and youth through, for example, reduced workload, enhanced livelihood security, enhanced food security, improved health.
ix. Promotes participation of women and youth.
x. Provides direct or indirect benefits at more than one segment of the value chain.
xi. The existence of an enabling policy environment (including legal and regulatory framework) that may influence the likelihood of scaling up.

The study was conducted over a five-month timeframe (December 2016 - April 2017), using a qualitative, participatory approach involving all value chain actors and based on a six-step process (see Table 4). This approach not only helped in generating relevant knowledge, but combined this with immediate engagement of policy-makers and development practitioners, enhancing the possibility that findings will be applied in development programming.

Table 4: Six-step process for the study

Steps	Purpose	Approach
1. Inception meeting	Build a common understanding among the consortium members and develop the approach	Consortium team meeting
2. Best practices identification (incl. value chain mapping)	To identify existing best practices at the national and regional level	Key informant interviews/expert opinions Document review
3. Analysis of climate smart investment options	To collect more data and information on climate impacts and responses (with a focus on best practices) along the VC	Focus group discussions at different stages of the value chain
4. Further development of best practices	To identify a combination of best practices most relevant to the southwest dairy value chain	Data analysis from the field
5. Dissemination and validation	To present and validate key findings	A regional multi-stakeholder meeting (MSIP) bringing together all value chain actors and segments
6. Reporting	Analysis and synthesis of all the results.	Consortium team meeting

Figure 6: Dairy Regions (Milk-Sheds) of Uganda (DDA, 2010)

2.2 Geographical Scope

The study focuses on the southwest region to build on existing partnerships and initiatives under implementation by the various partners that formed the consortium. SNV, the lead partner, currently implements the TIDE project, which focuses on piloting interventions to enhance production at the farm level.

The southwest dairy region is one of the six dairy regions ("milk sheds") of Uganda (coloured dark brown in figure 6). The other regions include: central (yellow), eastern (red-brown), Karamoja (grey), northern (green), and mid-western (pink). These are located in different agro-ecological zones and exhibit characteristic differences in the dominant livestock production systems and the major livestock value chain activities.

Although the investigation was conducted in the southwestern milk shed, the key findings and recommended best practices for enhancing resilience of value chain actors are likely to apply to all the milk sheds.

2.3 Data Collection

A combination of research tools was applied, including: document review and policy analysis; interviews with key experts; focus group discussions at three different levels of the dairy value chain (input supply, production and processing, transportation and marketing) and a multi - stakeholder dialogue with value chain actors in the southwest region. Data from different information sources were triangulated to assess information reliability.

2.3.1 Literature review

The research team conducted a review of the literature available online on climate impacts and responses in the dairy sector in Uganda and globally. Additional documents (e.g. climate-smart best practices, relevant policies) were collected from individual experts and organisations involved in the dairy sector and/or in climate change in Uganda.

Many research and development projects have been implemented with the aim of generating knowledge on climate change and developing interventions to enhance resilience and reduce emissions. Some of the information has been published online in the form of reports, scientific papers, conference proceedings and books. There are many unpublished documents, such as project reports, brochures, conference/ workshop papers, conference proceedings, strategies, policies and policy briefs, among others, that are held by organisations and individual members of the climate change community of practice.

2.3.2 Key Informant Interviews

Face - to - face interviews were conducted with dairy value chain actors, climate change champions and members of the community of practice on climate change, as well as policy, research and development practitioners. Persons interviewed came from the private sector (dairy cooperatives, Uganda Crane Creameries Cooperative Union, milk traders and dairy processors, financial institutions); government agencies (various ministries, including Ministry of Water and Environment, Dairy Development Authority and National Agricultural Research Organisation); local government extension workers; dairy sector NGOs and development partners (Heifer International, aBi Trust, Food and Agricultural Organisation), as well as international research organizations. An interview guide was prepared and used to collect data on known interventions/ practices that enhance the resilience of value chain actors and reduce emissions. Table 5 shows the Key Informant Interview guide.

Table 5: Key Informant Interview guide

i.	Title of adaptation/ mitigation measure (intervention)
ii.	Brief description of the intervention
iii.	Location of the intervention
iv.	Type of climate hazard addressed
v.	Contribution to adaptation/ mitigation
vi.	Impact (expected/ unexpected) on value chain actors (men, women, youth)
vii.	Segment of the value chain (inputs, on farm, bulking & transportation, processing)
viii.	Implementation stage of the intervention (pilot, scaling up)
ix.	SWOT analysis of the intervention
x.	Target users/ beneficiaries of the intervention (men, women, youth)
xi.	Investor/ promoter/ facilitator involved (private sector, NGO, government)
xii.	Policy, legal & regulatory framework and institutional issues

xiii.	Potential for commercialization (viable market demand, investor interest and financing)
xiv.	Source of information, interviewer and date

2.3.3 Focus Group Discussions (FGDs)

In March 2017, six FGDs with a total of 73 participants were conducted at different stages of the dairy value chain in southwest Uganda as summarized in table 6. The objectives were to understand how different actors along the value chain perceive climate impacts and how they are already responding.

Table 6: Overview of FGDs conducted

Level of the value chain	Number of FGDs conducted	Location	Number of actors	Gender ratio
Input supply	1	Mbarara	12	12 m
Milk production	3	Kyampangara – Kiruhura Karera – Sheema; Bukanga - Isingiro	17 18 17	6 f & 11 m 5 f & 13 m 4f & 13 m
Milk collection, bulking & transportation	2	Mbarara	6	1 f & 5 m
Milk processing	1	Mbarara Municipality	3	1 f & 2 m

Key: f = Female; m = Male

During the FDGs, the facilitators avoided using the term ‘climate change’ to prevent creation of any biases and confusion between climate variability and climate change in the discussions. Experienced resource persons facilitated the discussion. Participation of women and youth (30%) was promoted through deliberate invitations.

Discussions were guided by the interview framework developed for the FGDs (Table 7).

Table 7: FGD Interview Framework

i) Understanding of the main climate hazards in the area and description of those climate hazards ii) How are these climate hazards impacting on the dairy value chain activities of participants? iii) How do participants and other value chain actors respond to prevent or reduce effects of climate hazards? iv) What do participants regard as the most effective or successful responses for preventing or reducing negative effects of climate hazards on the dairy value chain? v) What prevents some value chain actors from implementing the responses mentioned above? vi) What should be done to enhance adoption of interventions (practices) to prevent or reduce negative effects of climate hazards on the dairy value chain?

2.3.4 Expert Panel Discussion

As part of the research, a panel of experts (Reference Group) was established, comprising of 12 technical experts on climate change and the dairy value chain as well as research, policy and development practitioners and private sector players. The Reference Group was involved in generating data on specific climate change practices, validating findings from the Key Informant Interviews, Focus Group Discussions and MSIP, and in analysing and determining the final choices of best practices. Two Expert Panel Discussions where convened. Participants included experts from Food and Agricultural Organisation (FAO), Ministry of Agriculture, Animal Industry and Forestry (MAAIF), National Agricultural Research Organisation (NARO), Ministry of Water and Environment and the Insurance Association of Uganda. Others were members of the research team from Wageningen University, International Institute for Sustainable Development (IISD), Mbarara Zonal Agricultural Research and Development Institute, Mbarara University of Science and Technology and the SNV/Netherlands Development Organisation.

2.4 Data Analysis

The research team analysed the data collected at different stages of the research processes using qualitative techniques. Participatory methodologies included perception of value chain actors, scoring, priority ranking and matrix ranking using criteria developed by technical experts. Section 5.1 gives a detailed description of the process used to identify and rank the best practices. The Reference Group validated the key findings and recommendations.

2.5 Dissemination of Findings

A number of approaches were used to create stakeholder awareness of the key findings of the study and to encourage implementation of the recommendations. During the research, key dairy value chain stakeholders, particularly policy and development practitioners, were exposed to the key findings and recommendations emerging from the study. This was the approach used, both during the focus group discussions, but particularly during the convening of the Dairy Multi-Stakeholder Innovation Platform (MSIP). In the MSIP, the key findings and recommendations of this assignment were shared with a wider audience of dairy value chain actors. The MSIP that took place in April 2017, attracted 47 participants drawn from the different value chain segments. Participants were inputs providers (pasture seed producers, animal feed suppliers, chemical & drug suppliers, equipment suppliers & artificial insemination providers); financial institutions (DFCU bank, Post Bank, Centenary bank, Pride Micro Finance and SACCOs – Rushere & Rwanyamahembe); insurance companies (Jubilee, UAP &ICEA); Dairy farmers cooperatives (primary, district unions and apex union); commercial dairy farmers; practical dairy training farms; representatives of milk traders and transporters; representatives from the retail segment (supermarkets); dairy processors; government institutions (NARO, DDA, Operation Wealth creation, extension officers, Local Government leadership from Mbarara district), Mbarara University of Science and Technology (MUST) and other NGOs such as Heifer international. The participants provided more inputs on the best practices and potential areas for investment by the private sector.

3. CLIMATE HAZARDS, IMPACTS AND RESPONSES

This chapter describes how key actors in the dairy value chain in southwest Uganda perceive climate change and what they consider suitable interventions to strengthen resilience. The chapter is structured in sub-themes.

3.1 Current climate hazards

Table 8 summarizes the main climate hazards as identified by dairy value chain actors, such as:

- **More erratic (unpredictable) spatial-temporal rainfall patterns** were highlighted as a key climate hazard. Value chain actors across the different segments suggested that the total amount of rainfall received has dramatically reduced and that distribution has changed. The farmers are using their own experience: "....*Rains in the evening used to indicate continuous rainfall whereas rains in the morning used to indicate that the rainy season is coming to an end. The trend has completely changed...*" (FGD with farmers in Kyampangara). Actors perceive that rainfall is patchier than before and that the intensity, especially at the on-set, is destructive, causing damage.
- **Higher ambient temperatures and prolonged droughts**. In addition, actors thought there is less dew and mist than before.
- **Windstorms** are another hazard mentioned, but this is specific to farmers in Kyampangara (in northern Kiruhura District). Farmers in this region are probably worse hit by windstorms compared to the other zones where we conducted FGDs in the region. But this is speculative and requires further investigation.

In general, the participants perceive significant changes in the prevailing local climatic conditions. Participants above 50-years of age provided examples of changes in climatic conditions experienced in their lifetime. Climate experts do not necessarily agree with these views, as Nimusiima et al (2013) state that the total amount of rainfall received in the region has not necessarily changed, but variability in the number of rainy days, intensity, and spatial distribution of the rainfall has occurred.

Table 8: Climate hazards identified during FGD by dairy value chain actors in the various segments in the southwest region

Climate Hazard	Input Supply	Milk Production	Collection, Bulking and Transport	Milk Processing
Prolonged/ severe drought (reduction in surface water, spontaneous loss of wetlands)	1	1	1	1
Higher ambient temperatures (less dew and mist)	1	1	1	1
Unpredictable rainfall patterns and amounts (spatial and temporal distribution of rains has changed; rainstorms are more destructive)	1	1	1	1
Wind storms (" winds are more violent and direction of wind which brings rains has changed")	0	1	0	0

1= hazard reported by participants (value chain actors); 0 = hazard not reported by participants

3.2 Perceived climate impacts on the dairy value chain

Climate impacts on the dairy value chain are seen to be most pronounced at the production level and include reduced availability of water and feed resources for the animals, especially during prolonged droughts. These impacts result in a reduction in milk yield, increased occurrence of disease and animal death, reduced incomes, amongst others (for more details see table 9). The impacts at production level, in turn, significantly affect the other segments of the value chain because they all depend on the quantity and quality of milk produced.

It should be noted that some of the claims made by the participants during data collection are not clearly understood and therefore require further investigation. For instance, the extent to which climate impacts animal reproduction potential, demand for chilled products, transport costs, among others, cannot be quantified. For details, see annex 1.

3.3 Responses (Interventions) by Dairy Value Chain Actors

In the previous sections we have noted that actors are aware of the effects of climate change, and they have started to respond to these challenges, or are aware of potential responses. We recorded the responses from our FGDs in table 9, structured according to themes that we arrived at by considering the results of our literature review and expert informant interviews.

The practices identified are either at pilot level, or include those that the participants in our primary data gathering think would be appropriate to increase resilience in the dairy value chain. Practices that enhance or maintain productivity in terms of milk yield, cattle numbers, body condition and reproductive performance of the farm during an adverse climate event, such as drought, are ranked among the best practices. These practices are followed by those that help the farmer to earn extra income, for example, from sale of pasture seed, conserved fodder, harvested water, timber, or practices that help the farmer to save money that would otherwise be spent on acquisition of farm inputs such as energy, water, fertilizer and animal feeds.

Table 9. "Best practices" for climate adaptation/mitigation identified by dairy value chain actors in the southwest region

Themes	Practices identified by value chain actors
A. Pasture and rangeland management	• Planting of improved [high yielding, early maturing, drought tolerant] pasture • Forage conservation [hay and silage making]; commercialization of forage production by processors, cooperatives • Paddocking for protecting improved pastures and managing grazing patterns (esp. during dry season) • Reducing herd size • Rangeland improvement/rehabilitation [incl. fencing, removing weeds, planting legumes, manure, tree planting]
B. Feeds /concentrated feeds	• Feeding of crop residues and agro-industrial by-products (e.g. brewers spent grains, molasses and maize bran) • Supplementary feeding with commercial or homemade concentrate (e.g. dairy meal, multi-nutrient blocks)

C. Water for agricultural production and irrigation	• Rainwater harvesting • Construction of valley dams and tanks in appropriate sites • Promoting use of pour-on acaricides which do not require water for application
D. Manure & waste management	• Biogas production
E. Animal housing	• Construction of cow sheds, stables, animal houses and calf pens using locally available materials such as grass thatched roof helps to reduce heat stress
F. Improved genetics (appropriate breeds) and animal health	• Cross breeding of local and exotic dairy breeds through artificial insemination
G. Equipment (cooling, processing, transport, storage, energy	• Solar systems used to operate milk coolers in areas without electricity (being piloted by SNV TIDE project and Makerere University: permits storage of evening milk and marketing it the following day) • Processors/traders/cooperatives providing milk chilling facilities closer to the farmers (being scaled -up by aBi Trust: helps to reduce post-harvest losses due to milk spoilage associated with high environmental temperatures)

Sources: Interviews and FGDs with value chain actors

3.4 Perceived barriers to adoption of 'best practices' for climate adaptation and mitigation

The main barriers to adoption of good practices in the dairy value chain highlighted in the FGDs include limited funds/financial resources, low milk prices, lack of knowledge and skills, attitudes and cultural values (Table 10). Poor access to credit was highlighted as a key barrier, exacerbated by lack of knowledge about available financial products from the banks, highly bureaucratic systems and processes, and the high interest rates charged on agricultural loans. Insurance was suggested as a potential solution, but was not widely understood.

Table 10: Barriers to adoption of "best" practices

Barriers to adoption of best practices	Input Supply	Milk Production	Collection, Bulking & Transport	Milk Processing
Lack of **funds** (limited financial resources)	0	1	0	0
Endless requirements to **access credit** (bank loans). Conditions for borrowing are discouraging	1	0	0	1
Banks are not creating awareness about low interest agricultural loans	1	0	0	1
Low prices of milk not motivating (the cost of input tend to be higher than the revenue from the outputs)	1	1	0	1
Measures are **expensive** (income from milk is still low) – high cost of investment	1	0	1	0

The costs of investment and implementation is very high	0	0	0	1
"Modern dairy farming" is not yet very profitable	0	0	1	0
Expensive inputs and services	0	1	0	0
Lack of knowledge and skills to practice the interventions	0	1	1	0
Lack of awareness about some of the measures	1	0	0	1
Poor farm planning	0	1	0	0
Peoples' **attitudes and mind sets are fixed** to what they are used to do	0	0	1	0
Fear of risk	0	1	0	0
Poor quality of animal drinking water	0	1	0	0

Note: The colours represent a categorisation in responses about adoption barriers: inaccessible credit (purple), investment barriers (green), knowledge gaps (orange) and attitudinal barriers (blue)

3.5 Recommendation to increase adoption of best practices

The participants in the FGDs suggested various ways that they felt could increase the adoption of the best practices by the different value chain segment players. These included:

1. Need for policy reviews on agriculture insurance – to make insurance schemes more accessible and useful to dairy farmers
2. Create awareness about available financial products in the financial institutions and how to benefit from them
3. Encourage exchange visits between the value chain segment members to areas of success in terms of best practices to facilitate further learning.

4. MAJOR CLIMATE SMART INTERVENTIONS IN THE DAIRY VALUE CHAIN

Based on the various inputs generated as part of this research, the research team has identified a number of key interventions that contribute to climate change adaptation and mitigation, listed and described in this chapter. It is based on the discussions in the FGDs (reported in the previous chapter), but also takes into account the inputs from the various other methods used (e.g. reference groups, literature review, expert interviews).

4.1 Rainwater harvesting and storage

Lack of water affects all the segments of the value chain. Purchasing water increases the cost of production and affects the level of profitability of the dairy enterprises along the chain. Rainwater harvesting is a very important practice that can strengthen the resilience of milk producers and has many mitigation co-benefits at farm level.

Along the dairy value chain, different actors require water for various purposes:

Input producers require water to produce various inputs, such as pasture seed and fodder crops, or grain and cereals for compound animal feeds.

Milk producers require water for various functions including:

i) **Consumption by dairy animals**. Milking cows require access to clean drinking water at all times.
ii) **Cleaning of milk utensils, milking parlour and stable/ cow shed**. In order to maintain good hygiene on the farm and produce quality milk, water is required to clean milk utensils and equipment.
iii) **Irrigation of fodder cops and pastures**. Irrigation reduces reflection of solar radiation from the earth's surface.
iv) **Domestic use.** Water is also required by dairy households for consumption, cooking, cleaning, washing, and other domestic purposes.

Milk collection/ bulking and transporters require a lot of water to clean milk coolers, insulated road tankers, cleaning floors, milk cans and other utensils.

Milk Processors require a lot of water: for every litre of processed milk, milk processors require 2-4 litres of water, mostly for cleaning.

Common methods of rainwater harvesting

While not all water required in the value chain can be obtained through water harvesting, it is one of the least utilised options so far, and fits very well in a climate smart approach. The choice of method for harvesting rainwater depends on the scale of operation and the purpose for which the water will be used. Traditional extensive cattle keepers, dairy ranchers and agro-pastoralists keep large herds of cattle that require a lot of stored surface water for animal consumption. The water is stored in valley dams or tanks. Initially, they largely served a communal function and were therefore constructed in strategic locations. However, cattle tracks that are required to access public dams are no longer available due to extensive fencing for pasture and disease control. As a result, the only feasible option that is being practised by cattle keepers is **private ownership of valley tanks**. Valley tanks have a smaller capacity than the dams and may be easily constructed using earth excavators. However, if not well sited and protected by planted trees, they are susceptible to extensive water loss due to surface evaporation and percolation.

Smallholder milk producers outside the cattle corridor, where most valley dams are located, however do not have access to reliable water sources to sustain the farm needs during severe drought. Most of these farmers depend on other natural water sources such as rivers, streams, wells and boreholes. These farmers may also invest in small-scale underground rainwater harvesting facilities made of a wide range of materials including dam liners, concrete, brick and mortar, plastic sheets and earth, as well as aboveground tanks made of plastic, concrete, iron sheets and clay pots. A **large underground water tank covered with a dam liner or wieldable plastic** may store large quantities of water capable of sustaining the needs of a smallholder farmer throughout an extended drought period, making the technology climate smart. The technology is cheaper to construct compared to other materials and may last as long as 25 years with minimal maintenance costs.

In the absence of piped water, rainwater harvesting technologies are a better option than natural water sources such as rivers and lakes. Rainwater harvested from roof surfaces may only sustain the water needs of small-scale enterprises and it is not a very reliable technology to use in order to enhance resilience against water scarcity during severe drought.

4.2 Planting of improved pastures/fodder crops plus forage conservation

The practice of planting improved pasture species that are high yielding, drought tolerant and faster growing is being promoted by a number of organisations. Some farmers have adopted this practice and are planting pastures especially for their milkers. The common pasture species and fodder crops include: Rhodes grass (Chloris Guyana), Brachiaria hybrid cv mulato, Guinea grass, Guatemala grass, kikuyu grass, Setaria, Napier grass (Pennisetum purperium), forage sorghum and maize. Pasture legumes such as Lablab, Centro, Siratro, Desmodium, Stylo, alfalfa (lucern) and Mucuna, as well as fodder trees such as calliandra, leucaena, Sesbania and Gliricidia are also grown, although the practice is yet to be fully adopted by farmers.

Planting of pastures and fodder crops is promoted alongside forage conservation, particularly hay and silage making. These not only enhance productivity and resilience of farms during drought, but also minimize loss of livestock due to forced sale of cattle and deaths associated with starvation. Aside from the yield-benefits related to these practices, farmers also benefit directly from the higher milk prices during the dry season. Higher revenue benefits not only the dairy farmers, but also milk traders and processors who would otherwise have operated below capacity.

While large scale forage conservation requires specialized equipment such as forage harvesters, hay makers, hay balers, rakes, forage trailers, forage choppers, tractors and silage block cutters, farmers in the southwest region have found alternative ways of conserving fodder by making appropriate equipment for chopping the grass/fodder crop and constructing makeshift wooden silos for their fodder.

4.3 Feeding of crop residues and agro-industrial by-products and their conservation

Use of crop residues and agro-industrial by-products as animal feed increases the diversity (availability) of feed resources during drought-induced feed scarcity. If appropriately prepared, it can contribute to a better composition of the animal ration, thereby contributing to climate change adaptation and possibly to a lower emission intensity.

Feeding animals on crop residues was found to be a common practice among dairy farmers. Common examples of crop residues and agro-industrial by-products being given to animals included maize (stover, cobs and bran), sunflower seed cake/ meal, beans (straw), brewers mash, rice (straw, bran), wheat (straw, pollard) and soya beans (straw, cake, meal).

Use of crop residues was predominantly being practiced by small and medium scale, mixed crop-livestock farmers. However the practice could be adapted to large-scale semi-intensive dairy farms as well, just like agro-industrial by-products. Minimal investment is required to store and provide the feed, but most farmers lack the required knowledge to handle, store and feed the animals. The biggest disadvantage of these products is their perishability and hence the need for their preservation.

An example of this practice is the sweet potatoes vine silage. Although sweet potatoes are a good source of energy (roots) and protein (vines), they are highly perishable. In order to make good use of sweet potato residues (vines and roots) they need to be conserved in the form of silage. Sweet potato silage is made by fermenting chopped vines and roots of non-commercial value. In the absence of air, it can be stored for up to a year. Its protein content and digestibility makes it an excellent complement to grass feeds.

Another example of the use of crop residues is the use of NARO feed pellets, developed by the National Livestock Resources Research Institute (NaLIRRI). The pelleted supplements are formulated from rations based on locally available feed resources such as leguminous forages, crop residues and agro-industrial by products.

4.4 Crossbreeding of indigenous cattle with appropriate exotic dairy breeds

Crossbreeding of indigenous cattle with exotic dairy breeds produces crosses that have intermediate traits of the indigenous and exotic breeds. The crosses produce higher milk yields than the indigenous breeds, their feed requirements are lower than that of exotics, and they are more tolerant of the harsh climatic conditions, including the tropical diseases, parasites and vectors.

Indigenous cattle to Uganda, such as Ankole and Zebu are very poor milk producers. The lactation length is short, and the average milk yield per lactation is less than 500 litres, compared with the 11,000 litres per lactation for some exotic breeds. The standard calving interval (interval between two calvings) for dairy cattle is 1 year, but that of indigenous breeds can exceed 2 years. Farmers intending to produce milk commercially cannot rely on indigenous breeds.

The current common exotic breed being promoted among dairy farmers is the black and white Holstein Friesian, which is a large breed with considerable feed and water requirements. It is thus not suitable for smallholder farmers who lack the capacity to conserve forage for dry season feeding. The smaller exotic dairy breeds such as Jersey, Guernsey and Ayrshire may be more suited and adaptable to the climate-induced food scarcity.

While pure exotic breeds offer more advantages to dairy farmers, they are more susceptible to harsh climatic conditions and to disease. Crossbreeding of indigenous cattle with exotic dairy breeds may produce crosses with intermediate traits of the indigenous and exotic breeds that stand a better chance of surviving the harsh climatic conditions; while giving higher volumes of milk than the indigenous breed. Projections using Livestock Analysis Model (LAM), suggests that breed improvement through crossbreeding will reduce emission intensity by approximately 15 % by 2030 (Ejobi et al., 2007). This makes the crossbred cow a better genotype for climate change mitigation.

4.5 Generation of Renewable Energy (Biogas) from manure and water harvesting

Intensive and semi-intensive dairy farms generate large amounts of manure, which is often applied in the field to improve soil fertility, particularly on mixed crop-livestock farms. When left to decompose naturally, manure can be a major source of GHGs, particularly methane (CH_4) and nitrous oxide (N_2O), which are emitted during storage and application of manure. Using manure to generate biogas is therefore an important climate change mitigation practice, if the bio-digester is used and maintained properly. If the biogas escapes into the atmosphere, bio-digestion might contribute to increased GHG emissions.

Apart from lowering emissions, the practice reduces dependence of rural households on fuel wood and charcoal for cooking and kerosene for lighting in rural homes. Where the volume of gas is large, the biogas can be used to fuel generators for electricity for household lighting and operations of simple machinery on the farm. This has the knock-on beneficial effect of reducing deforestation. Another positive spinoff of the practice is that the bio-slurry obtained from the bio-digester can be applied as fertilizer to increase yields of food and cash crops, as well as animal feed for poultry, pigs and fish.

Generation of renewable energy through biogas production needs to be combined with rainwater harvesting, as water is used in mixing the manure for feeding the digesters. During project monitoring, SNV found that in Kiruhura district, biogas plants were introduced, but 70% of the plants were found to be not operational because of the lack of sufficient water. Lwiza *et al* (2017) reported similar findings, indicating that biogas application requires a strong support sector (e.g. for repairs and extension advice on effective use), in order to generate sustainable impact (see also Roopnarain and Adeleke, 2017).

4.6 Use of solar energy to operate milk coolers

Milk is a perishable commodity, which quickly deteriorates after milking. High ambient temperatures hasten the deterioration process. In order to prevent deterioration of milk prior to processing, it should be stored at low temperatures (4 – 8^{o} C), within two hours after milking. The common practice within southwest Uganda is that after milking, the farmers then transport it to cooperatives or to trading centres, where milk coolers are installed at (most) milk collection centres.

Most coolers use grid power to operate, but owing to frequent power cuts, many have installed standby generator sets. In most rural areas of Uganda, milk coolers are operated fulltime by diesel generator sets owing to lack of grid power. Both diesel and hydro-electric power are expensive, and significantly increase the cost of chilling milk. Diesel generators also contribute to production of GHGs.

To address the above problems, milk cooling units have been developed that are operated by solar energy. Some of these are currently being piloted (e.g. SNV). At present, the pilot equipment is small-scale, but it is likely that the capacity of the solar system and cooler could be expanded to industrial scale.

Use of solar milk coolers addresses the problem of lack of grid power in rural areas, unreliable power supply and the high power tariffs and diesel prices. Solar energy is renewable, clean and much cheaper in the long run. Although milk coolers may be imported tax free, solar panels and related equipment are subject to import duties because they serve many commercial functions. This makes importing of medium- and large-scale equipment under the present conditions very expensive.

4.7 Innovative Agricultural Insurance and Financial Services

Limited access to credit has been cited by dairy farmers as the main reason for failure to invest in climate smart technologies and management practices. Banks are reluctant to offer long-term loans to farmers owing to the lack of reliable farm records, unpredictable climate risks, low profitability and lack of security. Many farmers only access small loans from savings and credit cooperatives, micro-finance institutions, and, in rare cases, commercial banks. However, the terms of borrowing are stringent. There is no grace period, payment terms are rigid and the interest rates are high. As a result, smallholder milk producers are not accessing credit to invest in climate smart technologies or innovations.

SNV is collaborating with financial institutions and dairy farmer organizations to negotiate favourable terms of borrowing, including a reasonable grace period, lower interest rates and flexible repayment conditions based on the rain-fed production cycle to enable milk producers to access loans for investment in rainwater harvesting technologies and other climate smart interventions. To improve the bank's capacity to predict the client's capability to repay the loans, the bank is working with insurance service providers to profile all potential customers with the aim of creating a database for assessing and predicting their potential to repay loans and access agricultural insurance products and services.

When implemented, the practice will enable dairy farmers to mitigate losses associated with climate risks by taking agricultural insurance products and accessing loans for investment in climate smart technologies and management practices. This will improve farmers' access to farm inputs, support services and improve the productivity of farms and household dairy income.

4.8 Integration of climate services in dairy value chain interventions

Access to climate information and related services is another challenge facing milk producers in Uganda. Government publishes seasonal weather forecasts in the major newspapers and shares the information on national radio and television, but it does not effectively reach the target farmers owing to their dependence on community radios and the high levels of illiteracy. Most farmers do not have access to newspapers and very few have television sets.

Innovative approaches for communicating climate information and delivering related services and technical advice are required to assist farmers to strengthen their resilience to adverse climate events and risks.

NGOs and development partners such as FAO, World Vision and SNV are piloting approaches to mainstream the delivery of climate services and information to dairy farmers by private dairy value chain actors and advisory service providers. The approach combines several strategies; such as collection of weather data, use of ICT (smart phones) to disseminate climate information, establishing community climate resource centres, and rendering technical advice on appropriate climate smart interventions. These approaches are likely to enhance uptake of climate smart technologies and management practices, and will ultimately contribute to strengthening the resilience of milk producers and other dairy value chain actors.

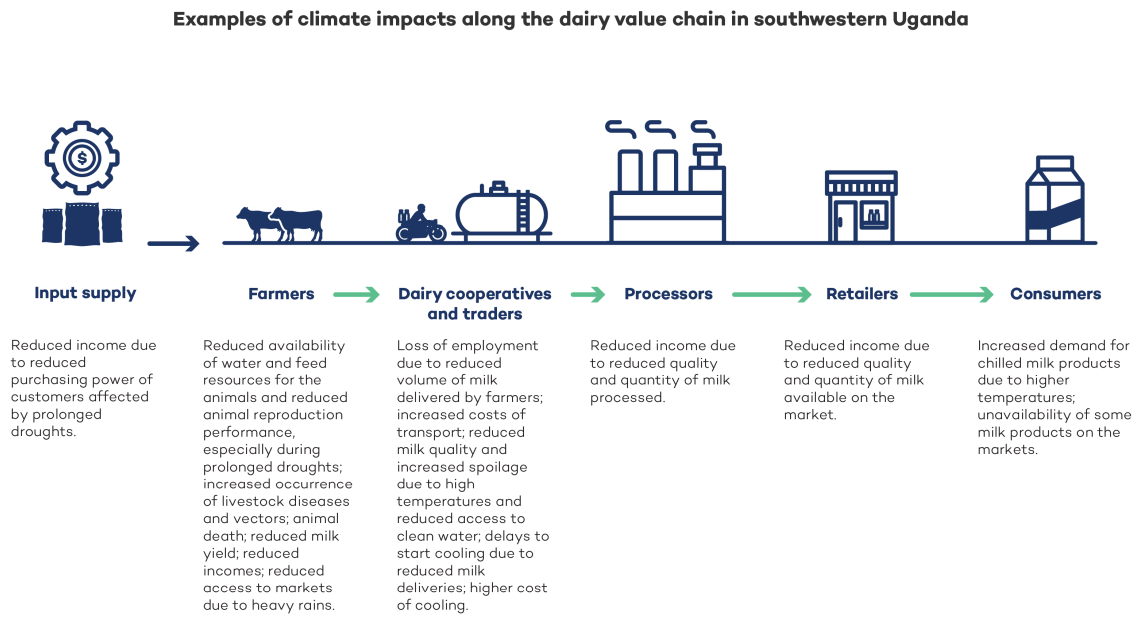

Figure 7: Examples of climate impacts along the dairy value chain in southwestern Uganda (source: Authors)

5. RECOMMENDED BEST PRACTICES

In chapter 2.1 best practices were defined as scalable and sustainable climate smart interventions that can be used to increase resilience and/or lower emissions in the dairy value chain. They cover technologies or management practices that i) support climate adaptation and/or mitigation, ii) are currently being applied or piloted at national level, or in the south western milk shed, iii) and are perceived as best practices by value chain actors. They also include policy interventions, institutional arrangements and information management innovations, among others.

Based on this definition, and the findings presented in chapter 4, it became evident that the identified individual practices have limitations in terms of adoption (change in practice) or impact, and may not fully deliver the desired results. Farmers already apply many of these practises, but usually on a piecemeal basis, as is evident from the Focus Group Discussions (chapter 3). In those discussions, the perception of value chain actors varied:

- For input suppliers, practices that build the resilience of their customers (farmers) are important, because the success of their business depends on the farmers' ability to earn money and purchase the inputs.
- Milk collectors, transporters and processors also ranked highest those practices that enhance the producers' resilience against climate risks, particularly drought, as it affects the supply and price of milk.
- The perception of milk producers varied with the level of climate risk they faced. After implementing measures to address a particular climate risk, the farmer ceased to recognize the associated adaptation measures as important. Instead, it was the practices that address climate risks for which the farmer is not well prepared, that were ranked highest.

Therefore, the practices listed in chapter 4 were evaluated further to come up with a **combination of practices** (best practices) that will enable their adoption. Selection and ranking criteria were developed (see annex 3), that combine the perception of value chain actors with scores based on a list of attributes relevant to all value chain segments and actors. These became the best practices as per the TOR of the assignment, and are further described in this section.

5.1 Planting of improved pastures combined with forage conservation, improving indigenous breeds and water harvesting

Each of these practices (improved pasture, forage conservation, improved breeding and water harvesting) has climate change adaptation and mitigation benefits. However, when implemented in combination, the practices maximize the benefits: high yielding, early maturing and drought tolerant pastures, together with increased availability of water, has a higher impact on productivity, when fed to improved breeds. Improved pasture management and fodder conservation improves cattle diets, which reduces GHG emissions (via enhanced digestibility) and improves herd performance. This combination of best practices can be integrated with climate services (section 4.8) to enhance its success.

5.2 Improving the efficiency of the value chain

This combination of practices aims to provide for an effective and efficient value chain process that links small-scale producers to processors while enhancing the provision of services. Smallholder milk producers in rural areas grapple with unreliable access to markets for their milk and have difficulties accessing high quality farm inputs and support services. Farmer groups operate in an opportunistic market, making it difficult for them to take decisions on longer-term investments for increasing milk productivity. At the same time, processors find it difficult to negotiate export contracts, without having access to reliable suppliers.

To overcome these challenges, an innovative arrangement of linking milk producers to processing companies is being adopted by SNV, in partnership with milk processors in southwest Uganda. In an earlier pilot, the East Africa Dairy Development (EADD) project developed the concept of service hubs, managed by farmer groups (cooperatives) as a platform to facilitate access to input and output markets as well as livestock services. In the model developed by SNV, processing companies sign supply contracts with milk producer groups. The producer groups commit to supply the processor exclusively with good quality milk in both the wet and dry season, and in return, the processor commits to supporting the farmers to increase production. This support will mostly consist of creating / improving access for farmers to suppliers of farm inputs and to livestock service providers, and strengthening the service hub role of the farming groups. It is in the interest of both parties to reduce the fluctuation in milk supply between dry and wet season: for the processor, it creates a more steady capacity utilisation, while for the producers, milk prices are highest in the dry season. Therefore, the supply contract arrangement will mostly focus on investment in climate smart agricultural technologies and practices that strengthen the resilience of milk producers to climate hazards and that reduce emissions.

In addition, it will also become possible for individual farmers, due to the supply contract relationship, to get an introduction from the processors to banks for accessing credit on recommendation from their producer group or cooperative. The processor negotiates with the bank in advance and guarantees the loans to the farmer group members. The processor again takes on the responsibility of remitting the loan repayments to the banks on behalf of the farmers who continue supplying milk through their groups or cooperatives to the processors. Through this approach, farmers would then be able to access agricultural loans without any hassle or collateral security.

6. ECONOMIC OPPORTUNITIES

This chapter describes the economic opportunities (EP) that emerge for private sector investment, as a result of implementing the best practices identified in chapter 4 and 5.

For this assignment, an economic opportunity is defined as the provision of a product or service that contributes to a climate change adaptation/mitigation best practice which the potential customers within the dairy value chain are willing to pay for. Economic opportunities identified are mostly in the production segment of the value chain, as this is where the effects of climate change are most felt and because upstream opportunities are determined by production-related activities.

The economic opportunities were developed by the research team and subjected to extensive discussion in the MSIP and the reference group meeting, using the following criteria:

a) Affordability of the best practice to the potential users within the value chain;
b) Potential for replication and dissemination within the existing and potential markets;
c) Potential for commercialization, and existence of demand for the service;
d) Investor interest.

Based on these criteria, the following potential economic opportunities were identified that the private sector could invest in in the southwest region.

6.1 Commercialization of forage production, conservation and marketing

Conservation and sale of fodder (in the form of hay and silage), as well as commercial forage processing services (which may include equipment hire services or actual mobile hay), and silage making services present an economic opportunity for the dairy sector.

In southwest Uganda, the concept of forage production and conservation has gained momentum as a result of the effect of climate variability on the production and supply of raw milk. Already, a couple of commercial farmers (for example, AGDI farm, and Grow More Ltd) have implemented this practice. Many producers of hay and silage confirm that the demand for conserved fodder exceeds supply in the dry season. In the current context of drought conditions in the southwest, this opportunity has a high potential for replication and dissemination. This is because it is cheaper to buy conserved forage in the long run from commercial producers, and the dairy farmers (potential market) are starting to appreciate the benefits. The level of milk prices will create further incentives to farmers to enter this market.

Further economic opportunities exist for input suppliers, including production, distribution and sale of pasture seed.

6.2 Improving dairy breeds through cross-breeding

Crossbreeding is an advantageous practice because the resulting animals may be adapted to local environmental conditions and produce higher milk yields under good management conditions. Use of artificial breeding technologies provides an opportunity to introduce high quality genetics and to disseminate the genetics widely with minimal investment.

If done in an effective manner that minimizes repeat services, and efficiently enough to reach the potential users on time, Artificial Insemination (AI) has the capacity to revolutionize milk production in the region, while improving capacity to cope with climate change and variability. This will make the service more affordable, increase its popularity, and thus support replication and dissemination, and create the critical market to support further commercialization of the service.

There are a number of opportunities that could support investment in this technology:

i. Farmers that are organized in cooperatives can be provided with the service on credit, with the payment collected through a check-off payment system against the milk collected.

ii. Willingness by dairy farmers to take on AI, as was reported in all focus group discussions that were conducted.

iii. Decreasing land size that cannot support free range grazing of bulls.

iv. Rising demand of milk (to support the many processing plants in the area and also to improve on the per capita consumption).

v. Job creation for the youth (AI services as technicians) and women (zero grazing).

vi. High demand for high quality heifers (as was reported in greater Bushenyi and Kabale) in the local and export markets (Rwanda).

Current supply of AI service is estimated at 600 inseminations per month, but the TIDE project AI model that is currently being piloted estimates that the demand for the service will grow to around 10,000 inseminations per month by the end of 2018.

In addition to provision of actual AI service, investment opportunities exist in the supply of the semen, AI kits and associated materials, Liquid Nitrogen supply and extension services provision.

6.3 Rainwater harvesting, storage and distribution

The importance of water in the dairy value chain cannot be overstated. Rainwater harvesting is a very important practice for strengthening the resilience of milk producers and has many mitigation co-benefits at farm level, and at other segments of the value chain. However, access to the harvested and stored water is critical to the productivity of the dairy cows. Taking water to the animals as opposed to taking the cows to water becomes a key activity, hence the need for water distribution (TIDE, June 2016). The feedback obtained from the MSIP indicated that there was a high demand for inputs and services related to water harvesting, storage and distribution and that there were already a number of investors involved.

Rainwater harvesting and distribution present business opportunities for farm diversification through vegetable growing on small farms and water reservoir/dam construction services. In the service sector, it creates jobs related to watering equipment, including novel equipment that enhances water use efficiency. Construction of large reservoirs using dam liners requires specialized technicians with the right equipment and skills. Construction of valley tanks and dams requires earth-moving equipment, which is too costly to procure and maintain on an individual basis. This therefore presents an opportunity for private sector actors to invest and hire their services to potential farmers. The use of solar powered water pumps is being promoted to improve the distribution of water within the dairy farms and milk collection centres. The supply of this technology provides a further opportunity for investors.

6.4 Innovative Agricultural Insurance and Financial Services for Milk Producers

Dairy farmers have cited limited access to credit as the main reason for their failure to invest in climate smart technologies and management practices. Banks are reluctant to offer long term loans to farmers due to the lack of reliable farm records, unpredictable climate risks, low perception of farming as a business and lack of security.

The TIDE project is collaborating with financial institutions and dairy farmer organizations to negotiate favorable terms of borrowing, including a reasonable grace period, lower interest rates and flexible repayment conditions based on the rain-fed production cycle to enable milk producers to access loans for investment in rainwater harvesting technologies and other climate smart interventions. According to the feedback from the MSIP, some financial institutions are working with agriculture insurance providers to profile all potential customers, with the aim of creating a database for assessing and predicting their potential to repay loans and access agricultural insurance products and services.

This will have the long term effect of making more affordable credit available to the dairy producers and is likely to grow the demand from the farmers for further financial products, hence having the effect of replication within the communities. It will enable farmers to mitigate losses associated with climate risks by taking agricultural insurance products and access loans for investment in climate smart technologies and management practices. Further opportunities exist for commercial banks to partner with NGOs, farmer groups and suppliers of production enhancement inputs to enhance the supply and utilization of the inputs that are climate smart.

7. POLICY ENVIRONMENT

Uganda's approach to climate change adaptation is to strengthen the country's resilience. This involves increasing food security, reducing poverty, increasing levels of education, promoting skills development, and enhancing the integrity of ecosystems. From a mitigation perspective, the country will adopt mitigation policies and practices that have adaptation co-benefits, expand renewable energy programs, promote energy efficiency and those that promote green growth and a green economy.

There is no specific policy for the dairy sector in Uganda for climate change adaptation. However, there are several policies, strategies and frameworks that guide and influence the development and uptake of climate smart technologies and agricultural practices in the dairy value chain. Uganda's Vision 2040 identifies climate change as a key challenge to development of the country. In the Second National Development Plan (NDP II) 2015/16-2019/20, mainstreaming of climate change is one of the national development obligations.

Livestock and agriculture are identified as priority sectors in the national climate change policy. Specific priorities include promoting and encouraging highly adaptive and productive **livestock breeds** in communities and **diversifying economic activities** to improve the resilience of rural communities dependent on climate-sensitive sectors such as agriculture and livestock rearing. The Nationally Determined Contribution (NDC) prioritizes adaptation actions in agriculture, including, among others, expanding **diversification** of crops and livestock, expanding **rangeland management,** expanding **small scale water infrastructure** and expanding **research** on climate resilient crops and animal breeds.

In the National Adaptation Plan (MAAIF 2017), the role of dairy production is recognized as a key element in Uganda's economy. Priority adaptation actions identified for livestock development focus on promoting climate resilient livestock production systems and value chains, including:

- Promoting and encouraging highly adaptive and productive livestock breeds
- Promoting sustainable management of rangelands and pastures through integrated rangeland management
- Promoting and encouraging diversification and improved livestock value chains

The rangeland management and pastoralism policy (2014) developed by MAAIF, recognizes climate change as one of the major challenges that needs attention for sustainable rangeland development. The Agriculture Sector Strategic Plan (ASSP) 2015/16-2019/20 of MAAIF, recognizes climate change as one of the 5 cross-cutting issues impacting the agricultural sector. Climate smart interventions planned for the dairy sector in the strategy include building capacity for **conserved feed production, marketing, on-farm water harvesting infrastructure and pasture and rangeland improvement**.

The government is also planning to strengthen the resilience of farming enterprises through the **Uganda Agricultural Insurance Scheme (UAIS).** This is a Public-Private Partnership (PPP) between the Government of Uganda and a consortium of 10 insurance companies to increase farmers' access to agricultural insurance services by lowering the cost of insurance premiums.

Government of Uganda set aside UGX 5 billion to finance insurance policies taken by farmers over a test period of one year, 2016/2017. Each insurance company develops its own insurance policies. The government contributes up to 50% of the premium for smallholder farmers, 30% for large-scale farmers and 80% for farmers in high risk areas. When farmers purchase the policy, the insurance company submits a request to government through the Insurance Regulatory Authority to pay its contribution for the policies taken by farmers. Farmers who suffer losses due to climate hazards and other insurable risks will be compensated by the insurance companies, which strengthens their resilience against climate change.

The current lack of a national dairy sector policy presents an opportunity for developing a climate responsive policy for the dairy industry. The policy could focus on promoting adoption of climate smart interventions that strengthen the resilience of vulnerable resource-poor dairy value chain actors and to lower emission from the industry. Such a policy will form a strong foundation for developing a competitive and sustainable dairy value chain in Uganda.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The results of the FGDs and the MSIP, conducted as part of this study, show that climate impacts on the dairy value chain are seen to be most pronounced at the production segment of the dairy value chain. Climate change events at production level cascade through the entire value chain because the other segments all depend on the supply of sufficient good quality milk. Stakeholders throughout the value chain identified those climate smart "best" practices as those that enhance or maintain productivity during an adverse climate event or those that help farmers earn extra income. A total of eight such practices were identified during the study:

1. **Rainwater harvesting and storage**: as availability of water is crucial to increasing productivity and resilience, a better and broader application of water harvesting and storage (as well as distribution) technologies is an important practice.
2. **Planting of improved pastures/fodder crops plus forage conservation**: this practice increases resilience, and as it makes a major contribution to reducing the large deficit in milk production in the dry season (as compared to the wet season), it also benefits the other segments of the dairy value chain.
3. **Feeding of crop residues and agro-industrial by-products and their conservation**: similar to the practice described above, its effects are mainly felt in the dry season with benefits cascading throughout the chain.
4. **Crossbreeding of indigenous cattle with appropriate exotic dairy breeds**: crossbreeds combine the high milk yields from exotics with tolerance to harsh climatic conditions of the indigenous breeds.
5. **Generation of Renewable Energy (biogas) from manure and water harvesting**: using manure to generate biogas can reduce GHG emissions, although water availability is a key ingredient for making this work.
6. **Use of solar energy to operate milk coolers**: solar power can address the problems of lack of grid power in rural areas (and are therefore a good alternative to diesel generators), and can also contribute to increasing the quantity and quality of milk across the supply chain if on-farm storage becomes feasible (increasing the utility of evening milking).
7. **Innovative Agricultural Insurance and Financial Services**: the use of smartphones can make it easier for dairy farmers to keep farm records, which are often a key requirement to access financial services for dairy farmers, including the application of relevant insurance products.
8. **Integration of climate services in dairy value chain interventions**: although these services are still being piloted, enhanced dissemination of increasingly available climate-relevant information can contribute to improved implementation of the various practices, listed above.

One of the findings of this research is that the individual practices, as described above, have limitations in terms of adoption (change in practice) or impact, and may not fully deliver the desired results. Most of the practices are already applied by farmers, though not yet at scale. This study therefore recommends a combination of key practices (best practices) that offer the best opportunity for the stakeholders to adopt and contribute to climate change adaptation and mitigation and to maximize their benefits.

The two key combinations of practices that are recommended are:

- **Planting of improved pastures, combined with forage conservation, improving indigenous breeds and water harvesting**: combining these practices maximises their benefits, and in some cases even enables their realisation. Providing supplementary feeding to dairy animals, but without simultaneously increasing availability of water, or alternatively providing the feed (and water) to animals with low genetic potential, increases production costs and may not generate the anticipated benefits (economic, resilience, greenhouse gas emissions).
- **Improving the efficiency of the value chain**: this can include a number of individual practices, as listed above, and mainly addresses the pre-condition under which they can be effective. By creating direct durable links between dairy producers and processors, investments across the chain (but particularly at production level) are encouraged and become feasible.

As part of the study, economic opportunities for investment by the private sector within the dairy value chain were also identified. Not by co-incidence, these economic opportunities fall squarely within the identified combinations of practices. After all, it is these combinations of practices that offer the biggest potential demand for users, have potential to benefit many stakeholders in the value chain and offer maximum benefits. They also contribute to overcoming the barriers to adoption of the identified best practices.

A well-functioning and integrated dairy value chain is critical to the resilience of the stakeholders to the climate change. It is also critical in providing the conditions for encouraging investment in the best practices identified in this research. However, a conducive policy framework is required to support this integration. Although there is no specific dairy policy on climate change adaptation and mitigation measures, several policies, strategies and frameworks that guide and influence the development and uptake of climate smart technologies and agricultural practices in the dairy value chain do exist. Two opportunities for policy influence were identified:

(1) The current lack of a national dairy sector policy presents an opportunity for developing a climate responsive policy for the dairy industry;

(2) There is a need for policy reviews on agriculture insurance, i.e. to make insurance schemes more accessible and useful to dairy farmers and other stakeholders in the chain.

Limitations

The study limitations call for further research in some areas to answer questions critical to the adaptation and mitigation function in the value chain.

Gender and youth perspective: The study had male–dominated groups across all the segments of the value chain. However, during the process of 'best practice' voting, the few women represented did not select significantly dissimilar climate change mitigation/adaptation interventions from the male participants. Although it is not envisioned that a significantly different selection of best practices would have resulted, had the FGDs been conducted with women only, this is an area that requires further research. Youth were lacking amongst the participants, especially at the production level. Further research is required to understand how to ensure a youth-inclusive dairy value chain.

Relevance of cooperatives: The farmers that participated in the FGDs were selected from those that are organised in cooperatives. We require data on those who are not part of the cooperative movement for comparison purposes.

Quantification of climate change impacts: The research work was exploratory in nature and used cross-sectional qualitative techniques. This approach left a major gap, particularly when quantities of emissions (and carbon sequestration) were required to judge the effectiveness or contributions of practices to climate mitigation and adaptation/resilience. Therefore, in order to quantify actual impacts, longitudinal, quantitative studies are required to establish GHG contributions.

Mitigation: The report falls short in describing potential mitigation effects of interventions. This is due to the fact that, for the stakeholders interviewed in this study, resilience and adaptation are more pressing and immediate needs.

Emission intensity: In this report, insufficient distinction is made between absolute GHG emissions (i.e. total CO_2-eq.) and GHG emission intensity (i.e. kg CO_2-eq. per unit of output). Most of the claims about reduced GHG emissions in the report are about emission intensity, but whether this will also lead to overall reduction of GHG will depend on many factors, that will need to be taken into account during implementation.

8.2 Recommendations

The research team, based on the findings from this research, defined the following recommendations:

1. Carry out a cost benefit analysis for each of the combinations of practices highlighted in this report to support their implementation, sustainability and up-scaling.
2. Create public awareness of climate change, associated risks, impacts and best practices to strengthen resilience of value chain actors and reduce emissions.
3. Support research to develop novel climate smart interventions and to undertake further investigation into the selected best practices, which are still in the pilot phase (e.g., application of solar milk coolers in large scale milk bulking and processing activities).
4. Develop innovative financing options, based on commercial models, and driven by the private sector, to support the development and dissemination of climate smart technologies.
5. Develop appropriate dairy sector policy and regulatory frameworks to facilitate mainstreaming of climate approaches in the production, handling, transportation, processing, distribution and retail of milk and dairy products.

6. Facilitate training of climate change champions in the dairy value chain, and sharing of knowledge and best practices among value chain actors in order to hasten uptake of climate smart technologies, innovations and management practices.

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1. ANNEXES

Annex 1: Climate Smart Interventions (Practices) Identified by Value Chain Actors

	Input Supply	Dairy farmer Group 1	Dairy farmer Group2	Dairy farmer Group 3	Collection bulking, transport	Processors
Rain water harvesting; Construction of dams and water harvesting; Construction of valley dams	1	1	1	1	1	0
Irrigation	0	1	0	0	0	0
Acquisition of appropriate dairy breeds	0	0	0	0	1	0
Reducing the number of cattle on the farm	0	0	1	0	0	0
Supplementary feeding	0	0	0	0	1	0
Fodder conservation (making hay and silage)	1	1	0	1	1	0
Planting improved pastures **Planting pastures**	1	1	1	1	1	0
Planting of trees	0	0	1	1	0	0
Paddocking	0	1	0	1	0	0
Fencing the farm-lands	0	0	1	1	0	0
Promoting use of pour-on acaricides (do not require water)	1	0	0	0	0	0
Creating **awareness** on climate risks, impact and best practices among dairy value chain actors	1	0	0	0	0	1
Working with service providers to provide **inputs on credit**	0	0	0	0	0	1
Investing in **storage space (for long life dairy products)**	0	0	0	0	0	1
Production of **long-life dairy products**	0	0	0	0	0	1
Offering farmers **high farm gate prices** in the dry season	0	0	0	1	0	1
Provide access to **agricultural credit** (especially finance)	0	0	0	1	0	0
Policy reviews **on agriculture insurance** – to make insurance schemes more accessible to farmers	1	0	0	0	0	0
Creating awareness about available **accessible financial products** in the financial institutions	1	0	0	0	0	0
Government should provide farmers with **low interest loans**	0	1	0	0	0	0
Enhancing access to credit for acquisition of vet drugs, improved dairy breeds, and construction of water tanks.	0	0	1	0	0	0
Empowering stakeholders with **knowledge and skills** (e.g. through technology demonstration farms, practical dairy training farms, exchange visits)	1	1	0	1	1	0
Training of farmers on farm management practices, improved dairy farming practices and environmental protection	0	1	1	0	0	0
Schools should teach **climate smart agricultural skills**	0	0	0	0	1	0
Training of technical skilled workers	0	0	0	1	0	0
Building **strong linkages** between researchers, extension workers and farmers	0	1	0	0	0	0
Construction of more **public valley dams and water wells**	0	0	1	0	0	0
Enhancing access to **machinery and equipment**	0	0	0	1	0	0
Need to **reduce taxes on farm inputs**	0	0	0	1	0	0
Government and NGOs' support to access **farm inputs and equipment** (e.g. tractors) eg through subsidies	0	1	1	0	0	0
Promoting processing of milk into **value added products** that can fetch high prices	0	0	0	0	1	0
Government **policy** to support all players in the dairy value chain	0	0	0	0	0	1

The research was carried out by the following consortium:

Profile: SNVs local long term presence has created strong and trusted relationships with multiple actors in the societies we work in. In Uganda SNV has been working for over 25 years and it has a team of experts in Kampala and another four offices throughout the country. SNV is implementing The Inclusive Dairy Enterprise (TIDE) project in 6 districts in Southwest Uganda, with funding from the Embassy of the Kingdom of The Netherlands (EKN). TIDE uses a business case approach, in which interventions are co-designed and implemented with the private sector, mainly from local businesses.

Profile: The Wageningen Centre for Development Innovation (Wageningen CDI) is a research institute of Wageningen University & Research. It focuses on the global challenges of secure & healthy food, sustainable markets, adaptive agriculture and climate change, ecosystem governance and conflict, disaster & reconstruction. They are linked to cutting-edge processes of innovation and learning with Wageningen UR's world-leading scientific and technical expertise.

Profile: The National Agricultural Research Organisation (NARO) is the apex body for guidance and coordination of all agricultural research activities in the national agricultural research system in Uganda. NARO is a Public Institution established by an act of Parliament, which was enacted on 21st November 2005.

Profile: Mbarara University of Science and Technology (MUST) was established in 1989, and has since grown from a single Medical faculty university serving a student population of 43 to a student population of about 4000 in 2016. As a science and technology institution, the university has strategically evolved into research and training disciplines that are relevant to National Development.

Profile: The International Institute for Sustainable Development (IISD) is one of the world's leading independent policy research centres. Established in 1990, IISD is a not-for-profit organization with offices located in Winnipeg (head office) and Ottawa in Canada, as well as in Geneva and New York. From these locations we engage over 250 staff, associates and consultants located throughout the world. Our mission is to promote human development and environmental sustainability through innovative research, communication, and partnerships.