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Building Climate Resilience for Dairy Farmers through Climate Smart Solutions: Insights from the Malawi Smallholder Dairy Sector

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Preface

This paper forms part of a set of five Climate Smart Agriculture (CSA) innovation model papers that are premised on the adoption and integration of various climate smart agricultural approaches to smallholder farming in East and Southern Africa (ESA). Funded by the United Kingdom's Department for International Development (DFID), the cases draw on pilot initiatives within the Agricultural Development portfolio of the Vuna programme. The pilot projects are country specific with different project components that are based on CSA. The papers explore the experience of different models designed to strengthen the delivery and uptake of climate smart agricultural practices, inputs and partnerships among smallholder farmers. Notably, the implementation period of the Vuna innovation models was short, ranging between 9 and 12 months. Consequently, the findings contained herein are based on emerging insights and the potential of the innovation models supporting farmer resilience in a scalable and sustainable manner. The innovation model series of papers sought to assess and identify early lessons emerging from the innovation model's adoption, uptake and ownership by implementing partners.

The series of the *innovation model papers* include:

- Building Climate Resilience for Dairy Farmers through Climate Smart Solutions: Insights from the Malawi Smallholder Dairy Sector (this paper);
- Integrating Climate Smart Agriculture in Pigeon Pea Production: Insights from Export Trading Group in Mozambique;
- Integrating Climate Smart Agriculture Capacity Development in Out-grower Schemes: Insights from Musoma Food Company Ltd and G2L Ltd in Tanzania;
- Integrating Climate Smart Agriculture into E-Voucher Farmer Input Subsidy Programme: Insights from Zambia; and,
- Building Inclusive Seed Systems for Semi-Arid Areas: Insights from Zimbabwe Super Seeds.

The research was conducted between October 2017 and February 2018, in three phases. First, available literature on CSA, climate change and agriculture in the focus country and within the region was reviewed. Second, desktop research of Vuna project documents (baseline reports, quarterly reports, grant application(s), and the Vuna project plan) was done. Third, field research was conducted to assess the extent to which the innovation model has been adopted and whether it is being adapted to enhance desirable outcomes for key value chain actors. Field research results were analysed to determine the potential for sustainability of the interventions.

Acronyms

ADD	Agricultural Development Division
ADF	Agriculture Development Facility
AI	Artificial Insemination
AVOs	Assistant Veterinary Offices
CAHW	Community Animal Health Workers
CC	Climate Change
CREMPA	Central Region Milk Producers Association
CSA	Climate Smart Agriculture
DAESS	District Agricultural Extension Services System
DAHLD	Department of Animal Health and Livestock Development
DFID	United Kingdom's Department for International Development
EPA	District or Extension Planning Area
ESA.	East and Southern Africa
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FICA	Flanders International Cooperative Agency
FIDP	Farm Income Diversification Programme
GDP	Gross Domestic Product
GHG	Green House Gas
IFAD	International Fund for Agriculture Development
IMF	International Monetary Fund
ITPAC	Industrial Trade Policy Adjustment Credit
KfW	German Development Bank
LDF	Local Development Fund
LUANAR	Lilongwe University of Agriculture and Natural Resources
MASAF	Malawi Social Action Fund
MBGs	Milk Bulking Groups
MDFA	Mpoto Dairy Farmers Association
MDI	Malawi Dairy Industries
MFASS	Malawi Forum of Agricultural Advisory Services
MK	Malawi Kwacha
MMPA	Malawi Milk Producers Association
NGO	Non-Governmental Organisation
OVOP	One Village One Product
PIHPR	Presidential Initiative for Hunger and Poverty Reduction
PPP	Public Private Partnerships
SHMPA	Shire Highlands Milk Producers Association
SNV	Netherlands Development Organisation
SSLPP	Small Scale Livestock Promotion Programme
TBC	Total Bacterial Count
ToT	Training of Trainers
USAID	United States Agency for International Development
VSO	Voluntary Services Overseas
WVI	World Vision International

Executive summary

Smallholder dairy farmers in Malawi face production, productivity and market related challenges that hinder the commercialisation of their dairy enterprises. Changing climatic conditions that have seen extreme weather conditions such as floods, prolonged dry spells, and drought in recent years have adversely affected the smallholder dairy sector. One of the critical components of dairy production that has been directly affected by climate change is the availability of adequate good quality nutritious fodder. In addition, producers face increasing risks to maintaining the quality of highly perishable milk products post off-take and increasingly demanding needs in terms of services in support of maintaining animal productivity, including breeding, animal husbandry, and animal health.

The Vuna programme's "*Building climate resilience for dairy farmers through climate smart solutions*" project sought to address the climate related challenges affecting dairy farmers in Malawi through a portfolio of activities. The innovation model used a public-private partnership approach to smallholder farmer development. The project worked directly with the Malawi Milk Producers Association (MMPA) - a business membership organisation, milk bulking groups (MBGs)[1] and Lilongwe Dairy as the off-taker in providing climate smart solutions to farmers.

Given the complex nature of the climate related challenges affecting the dairy value chain in Malawi, climate smart solutions offered were holistic in nature and sought to address felt needs affecting sustainable dairy sector development. The model thus offered an array of climate smart solutions that were tailored to address specific needs of the farmers and other market players. The solutions sought to: (i) improve provision of climate smart information and extension support; (ii) introduce technologies for improved milk storage and cooling; (iii) introduce new fodder production technology; and, (iv) improve general animal husbandry, breeding, and animal health service. Specific interventions included investment in hydroponic fodder technologies[2], legume intercrops, fodder conservation techniques such as silage making, piloting solar powered milk cooling technologies, introducing biogas digesters, as well as extension and skills development delivery in conjunction with milk production and processing market partners. In combination, these interventions increased the awareness and skills of dairy farmers to use improved strategies for fodder production, animal husbandry, milk handling and marketing. These interventions sought to increase animal productivity and the reliability of milk supply and, in turn, through better market access, realise improved incomes for farmers from dairy production, enabling further investments and expansion within the dairy value chain.

While it is too early to ascertain long term uptake of technologies, some adoption and adaptation is already evident. For example, training material content and delivery approach has developed over time with new materials and partners being added, while adjustments to the specification of hydroponic technologies by farmers themselves has encouraged additional uptake. Nevertheless, the high initial investments required for larger technologies such as the digesters and solar power units remain a constraint to wider uptake. The long term nature of the return on investment for such assets has proved to be a challenge for the sustainability and scalability of some interventions.

Emerging lessons from the Malawi dairy sector innovation case with regards model development and implementation include:

- In seeking to change prevailing practices, it is important that the change, or 'innovation' is clearly defined and understood by partners and its uptake closely monitored and evaluated.
- Relevant practice or service innovations are those based on clear and rigorous analysis of constraints. This maximises the likelihood of partner buy-in and uptake, but also ensures that technologies or other interventions address the root causes to which they are intended.

1. An MBG is a collection centre that caters for dairy farmers within a radius of 8 kilometres.
2. Hydroponic fodder production system is a continuous process of growing fresh fodder in a greenhouse structure within 7-12 days and fed as a supplement in the form of sprouts that are dried for six hours, common seed that farmers are using in Malawi for fodder production are sorghum, white maize, yellow maize, and millet

- The introduction of appropriate technologies and innovations requires understanding of the wider innovation landscape and lesson learning, as appropriate, from similar systems and/or initiatives.
- A primary objective of any pilot of a new practice or innovation is to establish and/or prove a clear and valid business case necessary to underpin uptake and sustainability. Effective measurement frameworks are a pre-requisite to capturing and documenting that business case.
- The long term sustainability and scale of wider uptake of any new practices or technologies requires that beneficiaries recognise and increasingly shoulder a significant (and, ultimately, all) proportion of the costs of those practice changes.
- The various CSA initiatives introduced by the project have relevance in addressing challenges that result from a changing climate but there are entry barriers with respect to green energy options, which prohibit uptake of such technologies. Accessible financing arrangements and installation cost-cutting measures are required to improve affordability. In addition, reliable supply and back-up arrangements need to be put in place.
- The entry level for each CSA technology should be informed by rigorous needs and risk analyses as well as a cost benefit analysis. For example, with respect to the CSA fodder supply arrangements, market analysis recommends that a business case be developed for an entrepreneur to produce and market hydroponic fodder to dairy farmers within MBGs. This business opportunity is based on market dictates and therefore has a better chance of demonstrating impact and can also embrace other technologies such as silage production and urea treatment.

1 Introduction

Climate change is altering rainfall patterns and inducing more severe and frequent extreme weather events such as droughts and flooding in many parts of East and Southern Africa (ESA). These changes threaten to deepen the challenges already being faced by millions of farming households. The situation is even more alarming in regions that are already semi-arid where climate risk is endemic. Unless decisive adaptation action is taken to build resilience of the agricultural sector, food insecurity and poverty are set to worsen. Effective response measures are urgently required to sustainably increase productivity, stabilise yields and diversify production systems while building the adaptive capacity and resilience of farming communities.

Climate Smart Agriculture (CSA) is a promising adaptation approach for the agricultural sector that has gained much traction among governments, non-governmental organisations (NGOs), private sector and donors. CSA has been formally defined by the Food and Agriculture Organisation of the United Nations (FAO) as consisting of three components: (i) sustainably increasing agricultural productivity and incomes; (ii) adapting and building resilience to climate change; (iii) reducing and/or removing greenhouse gases emissions. The concept of CSA has now been widely adopted at various levels. Significant levels of national and international funding are correspondingly being allocated to the development and promotion of CSA. A key challenge is prioritising an extremely broad array of agricultural practices, technologies, institutional arrangements, and activities now being called "climate smart". Equally lacking is an understanding of both the effectiveness and sustainability of different models for rolling out CSA.

In Malawi, the dairy sector is negatively affected by adverse weather caused by climate change. Constraints faced by dairy farmers include: poor availability of adequate on-farm high quality nutritious fodder; lack of genetically appropriate dairy cows; lack of knowledge, skills and training on CSA practices; poor dairy infrastructure and equipment at milk bulking groups (MBGs); and poorly functioning input and output markets. The Vuna supported *Building climate resilience for dairy farmers through climate smart solutions* Project provided an opportunity to address adaptation needs within the smallholder dairy value chain. The project worked directly with the Malawi Milk Producers Association (MMPA) and Lilongwe Dairy as the off-taker in providing climate smart solutions to these challenges.

Vuna's Agriculture Development Facility (ADF) portfolio of pilot projects was intended to test a number of different (and hopefully more effective and more sustainable) approaches to enabling farmers to adopt and use an appropriate mix of CSA practices and technologies. This pilot project used a dairy industry association as the point of entry and worked with them and private sector companies to build resilience to climate change within the smallholder dairy farming sector. The project sought to facilitate the development and adoption of viable CSA options for dairy farmers and support dairy market chain interventions. Those results would inform decision making for and by other MBGs in Malawi. Key partners and networks would establish information flow in and out of the project to benefit the project and to influence others. The project aimed to provide a model for wider use within the industry, thus leading to much greater adoption of CSA, contributing directly to Vuna's programme outcome. This paper seeks to assess what worked and what could work better and provide recommendations for the MMPA and Lilongwe Dairy to integrate into their innovation models.

While the insights shared in this paper are intended to answer questions on the effectiveness of private sector-based approaches to achieving developmental outcomes, they will potentially influence future designs of climate smart investments in smallholder systems. The paper sets the scene with a brief description of the local context, including the livelihood system in the areas of focus, the nature of climate risks facing farmers, key trends in climate change and the structure of the market system within which MMPA operates. This is followed by an overview of MMPA and Lilongwe Dairy's business models, emphasising its main features, its theory of change, key stakeholders and their roles (Section 2). The main analytical sections of the paper (Section 3 and 4) assesses the adoption of MMPA and Lilongwe Dairy's business models and the extent to which it was adapted to ensure sustainability. The paper concludes with a summary of key lessons and recommendations for model improvement (Section 5).

1.1 Local livelihoods system

Generally, the farmers in the Southern part of Malawi where the project is anchored are densely populated with limited livelihoods options compared to their Northern region counterparts. Apart from dairy, other livelihoods options are tea, cotton, groundnuts, sugar and coffee. The Southern region has tea and coffee estates and some farmers have tea plots that are no longer commercially viable. In Malawi, tea accounts for close to 9 % of all export earnings. It is the largest formal employer in the country with more than 60,000, predominantly poor people, working during the peak plucking periods, and a further 1.5 million people benefiting from the sector through forms of outgrower arrangements and employment in ancillary industries. The majority of the dairy farmers also produce horticultural crops such as tomatoes, cabbage, leafy vegetables, and carrots among others. They also grow maize as a staple crop, which is sold either as dry grain or fresh cobs, especially during summer.

1.2 Climate risks and impacts

As a result of high population growth triggering rapid deforestation and soil erosion, Malawi's agriculture sector is particularly susceptible to the negative effects of climate change (Figure 1). In the last two decades, Malawi has experienced several adverse climatic hazards such as dry spells, seasonal droughts, intense rainfall, and floods.[3] These hazards increased in frequency, intensity and magnitude, and have adversely affected food and water security, water quality, energy and sustainable livelihoods of most rural communities. An assessment of drought events in Malawi over a period of 20 years from 1980 to 2000 indicates widespread incidents of drought across the country as illustrated in Figure 1 (middle). The highest drought incidents occurred in the Southern province with a recurrence of 10 events. The other provinces had incidents ranging from approximately four (lowest) to eight. In terms of flooding (Figure 1, right), the Southern province of Malawi experienced the highest

Factors such as high population growth, rapid deforestation, and widespread soil erosion have significantly contributed to climate change in Malawi. The impacts of climate change are being manifested in various ways such as intense rainfall, changing rainfall patterns, floods, droughts, and prolonged dry spells. Being an agro-based economy almost all sub sectors including dairy farming have been affected by climate change. For instance, droughts and prolonged dry spells have led to scarcity of feed for dairy animals especially during summer season, hence affecting milk volumes.

Box 1. Climate Risks

3. Mohamed A. Salih - 2014 - Business & Economics

incidents with a recurrence of seven events (Annex 1). For instance, the 2015/2016 El Niño weather conditions resulted in prolonged dry spells in most parts of the South and Centre with some flooding in the North.[4] During this growing season, the country received at least three episodes of prolonged dry spells each lasting 4-7 weeks for Southern region districts, 3-4 weeks for Central region and about two weeks for the Northern region districts. A major impact of climate variability in Malawi is on the production of maize, the main food staple. Maize requirement for human and livestock consumption is currently estimated at 3,205,135 metric tonnes.[5] In 2015/2016 growing season the country produced 2,431,313 metric tonnes and 2,776,277 metric tonnes in the 2014/2015 growing season, representing a 12.4% decline. For detailed analysis of the Malawi Climate Risk analysis refer to Annex 1.

Key stakeholders across the value chain are fully aware of the impact of climate change on agriculture such as changing seasonality, decline in productivity and increase in disease incidence. Response options include fodder production and conservation (adaptation options in the short term), while irrigation and breeding build resilience in the medium to long term.

Capacity building on dairy related CSA issues at local and national level equips market actors with the requisite skills to mitigate the effects of climate change, while organised MBGs offer options for outreach and group synergies for high capital-intensive initiatives such as biogas and solar technologies. A high population of the *bos-indicus* zebu animals forms a good foundation for the breeding of adaptive dairy animals for use in the sector.

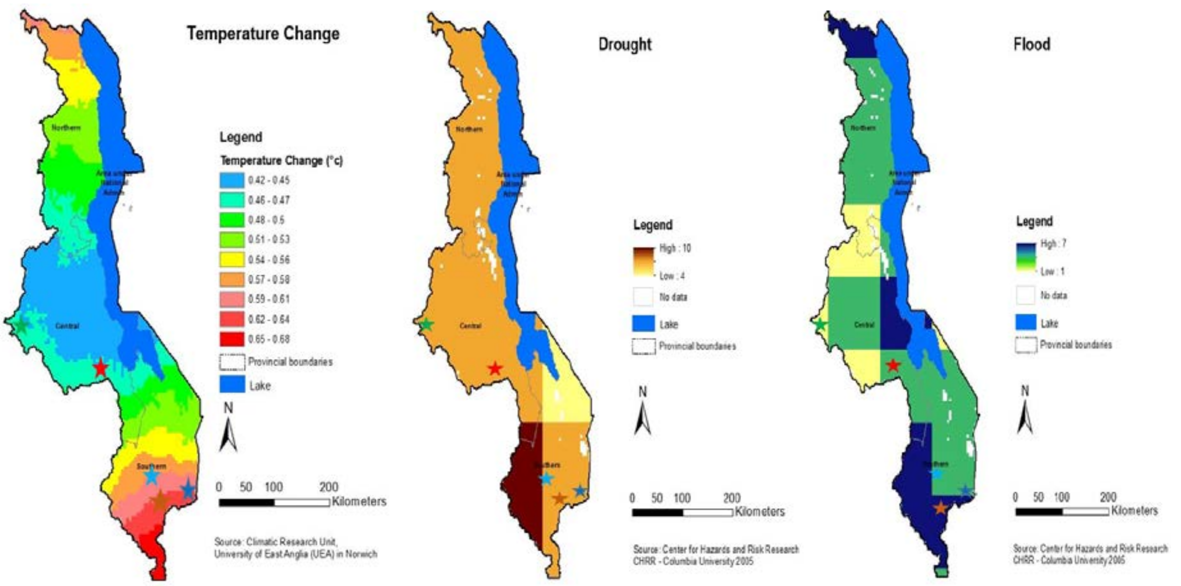


Figure 1: Climate Risk Map of Malawi: Temperature Change (left) Drought (middle) and Floods (right) in Malawi. The project sites are marked by stars. Green – Mchinji (1 MBG), Red – Dedza (3 MBGs), Light Blue – Chiradzulu (1 MBG), Dark Blue - Mulange (1MBG) and Orange – Thyolo (4 MBGs).

1.3 Structure of the dairy market system

The Vuna supported initiative in Malawi was implemented by MMPA and Lilongwe Dairy Limited. The MMPA is an umbrella organisation of the MBGs. Apart from its collective marketing functions; it is also a hub for extension services to smallholder farmers. The majority of farmers own an average of two cows and rely on a zero grazing system[6] as they

4. Malawi Drought 2015-2016 Post-Disaster Needs Assesment (PDNA)
5. Frederick B.M. Msiska July, 2016 National Market Analysis to Inform the 2016/17 MVAC Food Security Response Options
6. In a zero grazing system, livestock is permanently kept confined structures from where all feed and water is provided

farm on less than 0.4 hectares of land. The MMPA has three regional associations: Mpoto Dairy Farmers Association in the North (MDFA); Central Region Milk Producers Association (CREMPA) and the Shire Highlands Milk Producers Association (SHMPA) with the majority practising smallholder dairy farming. Ten MBGs in the Central and Southern regions were targeted under the Vuna supported project.[7] Out of 18,000 MMPA members, 2,021 smallholder dairy producers were targeted for the Vuna supported CSA interventions in Malawi.

According to MMPA, Malawi produces approximately 23 million liters of raw milk annually with 94% of this production coming from the Southern region particularly Thyolo, Chiladzulu and Mulanje belt under SHMPA. Per capita milk consumption is low at 4.9 kilograms per person per year compared to Tanzania (40 kilograms) and Kenya (98 kilograms). This is attributed to several reasons varying from cultural inclination to low milk consumption in the country and compounded by milk being over-priced for the average urban consumer . Milk consumed within the informal market is usually not computed when average consumption statistics are calculated. The Vuna project private sector partner Lilongwe Dairy collects raw milk from 26 MBGs, receiving and processing more than 56% of the country's milk intake. Other processors include Malawi Dairibord, Blantyre Dairies, Suncrest Creameries, MDI and Sable Farming/Mapanga Dairies.

In the North, milk is primarily sold raw to traders/middlemen. This is attributed to the absence of a processor collecting and processing milk from the region. A government owned processing plant, Northern Dairies, which serviced the area, was privatized in the mid-90s, together with Malawi Dairy Industries (MDI) and Dairibord. However, it could not take off in the early 2000s and was eventually shut down. Mpoto Dairy Farmers Association started a mini processing plant with some funding from the Flanders International Cooperative Agency (FICA) in 2010/2011. Milk was pasteurized, packaged and sold into the urban market of the city of Mzuzu. However, MDFA did not have the capacity to commercialize the business model. The association was meant to be the main off-taker of milk in the North but this did not work out.

Overall, milk production has been increasing over the past two decades. Government dairy projects coupled with development projects implemented by NGOs have contributed to the increasing trend. In the past decade, the private sector has invested in the dairy supply chain particularly breed improvement through placement of improved breed heifers and artificial insemination (AI) services – functions that were previously only performed by government and the NGO sector. Lilon processors engaging with farmers at the downstream of dairy supply chains to increase production of milk.

Lilongwe Dairy (2001) Limited is a private dairy processing company operating in the Malawi dairy sub sector. The company is based in Area 5, Lilongwe. The main products from the company include: pasteurised fresh milk, long life UHT fresh milk, yoghurts, UHT flavoured milk called 'Bliss' and also dairy blend fruit juice branded as 'Enjoy.' The company does not have a commercial dairy farm but relies on a smallholder led supply chain. About 92% of the raw milk is produced from Southern Malawi in the Thyolo, Chiradzulu and Mulanje area. Lilongwe Dairy is the largest buyer of raw milk, working with more than 2,300 smallholder dairy farmers organized in 23 MBGs.

Lilongwe Dairy has the largest market share of 56% among the largescale processors namely Suncrest Creameries, Dairibord Malawi Limited, Sable Farms and MDI. Malawi used to be the only country in the SADC region that was not producing Aseptic family packs (1,000ml packets), such as Long-life UHT Milk, Fat free/Low-fat Milks, Dairy Blends and Long Life Yoghurts in 1,000 millilitre family portions packs. These were all exclusively imported. However, towards the end of 2017, Lilongwe Dairy introduced family pack sizes for UHT Milk and Dairy Blends on the market.

Box 2:. Lilongwe Dairy Company

The not-for-profit organizations are also implementing different initiatives to promote dairying in Malawi. Most of them work with the government's Department of Animal Health and Livestock development (DAHLD), Agricultural Development Division (ADD), or Extension Planning Area (EPA) levels. Major development partners supporting dairy development in Malawi include the United Kingdom's Department for International Development (DFID), International

7. Six MBGs from SHMPA (Chizunga, Chonde, Matapwata, Namahoya, Thunga and Namitembe) and four MBGs from CREMPA (Bua, Chitsanzo, Dzaonewekha and Magomero). The target area excludes the Mpoto Dairy Association in the Northern region.

Fund for Agriculture Development (IFAD), United States Agency for International development (USAID), European Union (EU) – Farm Income Diversification Programme (FIDP) and German Development Bank (KfW). Some of the key NGOs who have contributed and are still implementing projects in the sector include WeEffect, Heifer International Malawi, Oxfam GB, and Small Scale Livestock Promotion Programme (SSLPP), Land O' lakes and World Vision International (WVI). Government projects such as Malawi Social Action Fund (MASAF), One Village One Product (OVOP), Local Development Fund (LDF), and Presidential Initiative for Hunger and Poverty Reduction (PIHPR) – which proposed a cow-a-family, have also contributed significantly to the growth of the sector.

1.4 The nature of the problem facing the Malawi Smallholder Dairy Sector

Smallholder dairy farmers in Malawi continue to face various interrelated challenges in addressing productivity, quality and market access. These can be broken down into 4 main areas:

1.4.1 Limited access to adequate good quality fodder

Many farmers lack consistent access to adequate volumes of quality fodder for feeding their animals (Figure 3).The majority of farmers rely on off-farm sources of fodder from as far as 15 kilometres. The collection of fodder from off-farm sources has resulted in conflict with macadamia nut and tea estates, with farmers arrested and fined, paying up to MK100,000. Some farmers use crop residue of low nutritional value to feed the dairy animals during the dry period, resulting in lower milk yields.

Despite the evident demand from dairy farmers and MBGs during the period of low fodder availability, a functioning commercial supply of fodder has yet to emerge. Similarly, the preservation of fodder practices present in other countries in the region such as urea treated stover and hay production remains limited.

Figure 2:. Farmer coping strategies in the face of feed supply constraints

1.4.2 Inconsistent energy supply

The electricity supply for milk cooling is unreliable. Cases of 16-hour power outages resulting in milk losses were reported at the visited MBGs. This often necessitates the use of old diesel generators which significantly increases operational costs. Smallholders and MBGs therefore lack access to cold chain infrastructure at the local level and they lack the necessary finance to invest in cooling technologies at farm or group levels. Renewable energy technology such as the use of solar and biogas that utilises animal manure is poorly understood and hence has not been actively taken up in the Malawian smallholder dairy sector.

1.4.3 Lack of adaptive and productive dairy breeds and poor support services

Dairy farmers lack access to adaptable and productive dairy breeds that suit their local circumstances. The indigenous *bos-indicus* breeds that are highly adapted to local diseases, parasites and nutrition have low milk yields even with good nutrition. Exotic, high producing breeds such as Jersey and Holstein are not locally available and have to be imported at high cost. These exotic breeds are also poorly adapted to the local conditions and are susceptible to diseases and parasites. Cross breeds that are both more productive and adapted to local conditions are not available.

The smallholder dairy sector remains under-served by both breeding and veterinary services. Breed improvement remains limited due to lack of capacity to utilise breeding technologies such as artificial insemination (AI) either at farm or MBG level. As a result, the supply of adaptive breeds through cross breeding with indigenous breeds is limited despite having significant potential.

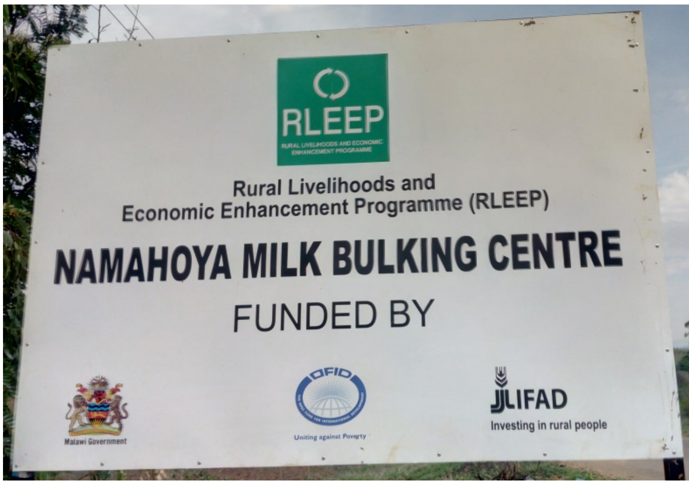
A cross-cutting challenge facing dairy smallholders remains access to extension, information and advisory services. The government has front line extension officers at EPA level called Assistant Veterinary Officers (AVOs) who are responsible for offering extension services in livestock, particularly veterinary services. Their training is however limited and often informal in nature. Only a few qualified veterinarians serve the smallholder dairy sector. No formal training institution provides training in veterinary studies especially at degree level. Most of the vets in Malawi were trained in other Southern African countries until four years ago when a Veterinary degree programme was introduced at Lilongwe University of Agriculture and Natural Resources (LUANAR).

1.4.4 Inconsistent access to markets

Lack of access to a reliable and rewarding market is the key challenge for most dairy farmers in Malawi. Currently, poor cold chain infrastructure represents the primary risk to milk quality, perishability and thus market value. Many smallholders lack timely access to reliable cooling facilities and large quantities of milk are spoiled daily.

2 Innovation model description

The Malawi innovation model sought to improve milk off-take opportunities for smallholder farmers through a partnership with Lilongwe Dairies by the provision of technical training; milk processing investments; milk testing facilities at MBGs and laboratory testing facilities at factory level; and milk processing and marketing. In turn, Lilongwe Dairy and MMPA extension staff received dairy related CSA training from Vuna and cascaded the same through MBG based staff to the farmers. Both institutions also provided business management and governance training in addition to fodder support services, green energy demo units, breeding and animal health support services. Through these activities, the project's objective was to increase the supply of good quality milk to the processor thus increasing farmer income and building farmer resilience against climate related shocks.



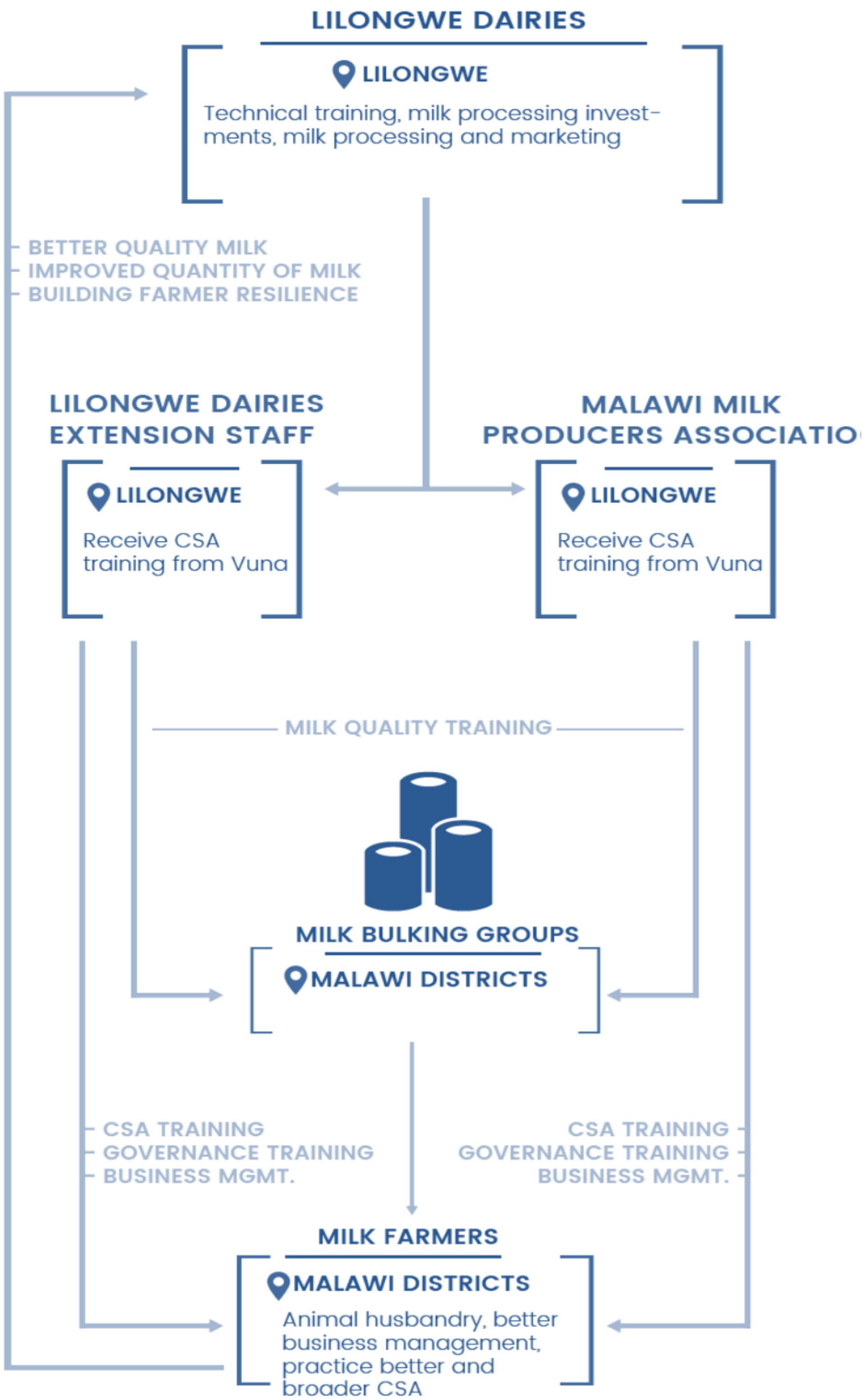


Figure 3:. Malawi dairy innovation model

2.1 Innovation model rationale

The interventions sought to build the resilience of smallholder dairy farmers under zero grazing production systems facing the adverse effects of climate change. Capacity building for better on-farm husbandry practices aimed to improve both production and quality of milk. This was achieved through training in CSA theory and practice at farm and institutional levels, and backup support services for the adoption of such practices. The project, in practice, consisted of multiple, complementary innovations:[8]

- Fodder production and preservation
- Renewable energy generating and methane-reducing manure management technology (biogas digester technology)
- Climate-efficient milk handling technologies (solar based cooling and storage)
- Productivity improvements through increased access to AI and veterinary services
- Water harvesting to take care of water supply requirements at farm and MBG level

The rational for adopting each is briefly described below:

Adoption and production of drought tolerant and/or water-efficient fodder crop varieties, primarily by dairy farmers themselves through improved intercropping of fodder crops sought to improve availability of adequate fodder supplies. The model raised awareness of the potential fodder market in the dairy sector and increased access to water-efficient fodder seeds and varieties. In addition, more intensive fodder production systems such as hydroponic production methods, were explored as a means of both demonstrating the possibility of intensive fodder production systems to supplement the fodder requirement needs of the dairy animals while also addressing the land pressure issues in some of the farming areas.

In seeking to reduce methane levels from animal manure the programme promoted climate-friendly manure processing technologies. Using biogas digester technologies, the programme aimed to demonstrate to farmers the cost savings possibility of the alternative energy source while making more climate-efficient use of manure. The installation of demonstration digesters aimed to raise awareness and encourage farming households to adopt biogas digester technology.

As part of increasing farm level productivity, the programme focused on the promotion of efficient and climate smart milk cooling and storage technologies. This not only aimed to reduce milk losses, but also as a cost and climate-efficient way through use of solar powered technologies that replace the use of diesel powered, high emission (greenhouse gas) and high maintenance generator technologies. The programme aimed to install and demonstrate the utility, reliability, and efficiency of solar powered cooling units at strategically placed MBGs to support wider demonstration, outreach, and adoption by other MBGs.

In further improving animal productivity, the programme sought to improve access to quality AI and veterinary services through the MBG structures. The premise was to utilise opportunity afforded by MBGs to aggregate producer demand for services and provide cost effective access to clients for AI and veterinary service providers.

2.2 The innovation model

The model relied on the MMPA and Lilongwe Dairy to partner with smallholder farmers in the development of the entire value chain through building CSA production and strengthening the commercial competiveness of the entire value chain. The two key partners in the project led on different technical areas as laid out in Table 1. Both partners carried out Training of Trainers (ToT) for Lilongwe Dairy and government extension workers on CSA practices such as new fodder

8. In addition the project supports water harvesting technologies. These target domestic not agricultural practices and are, therefore, not the subject of this Paper.

technologies (hydroponics, intercropping with legumes for forage and silage making) and other technologies (solar and rainwater harvesters). In addition to the shared responsibilities, Lilongwe Dairy led on milk quality assurance through testing at MBG and factory levels. Nevertheless, the activities of MMPA in practice extended beyond those originally set out and included AI to improve breed quality and therefore milk production potential through genetic improvement; lead farmer training as village based animal livestock workers; development of extension training manuals; training of farmers in legume intercropping, business management and savings schemes; and fodder and forage nurseries establishment.

For detailed elaboration of interventions undertaken at each MBG see Annex 2.

2.2.1 Key stakeholders and roles

Table 1: Key stakeholder and their roles

Stakeholder	Type of organisation	Roles
MMPA	Farmers association	• ToT -Lilongwe Dairy and government extension workers- on CSA practices such as new fodder technologies (hydroponics, intercropping with legumes for forage and silage from biogas digesters) and other CSA technologies (solar and rainwater harvesters) • Cascading training to lead farmers on new fodder technologies, farming as a business, CSA for dairy production, train Community Animal Livestock Workers (CAHWs) • Procurement and installation of inputs for technologies demonstrated (seed for hydroponic systems, biogas digester, solar, start-up treatment kits for CAHWs) • Promoting milk bulking to Lilongwe Dairy from 26 bulking groups • Village savings and loans training
Lilongwe Dairy	Private sector	• ToT -Lilongwe Dairy and government extension workers- on CSA practices such as new fodder technologies (hydroponics, intercropping with legumes for forage and silage from biogas digesters) and other CSA technologies (solar and rainwater harvesters) • Procuring milk on a non-contractual basis from participating farmers • Procurement and installation of inputs for technologies demonstrated (microbiology equipment at Lilongwe Dairy, Milk Hygiene Equipment,) • Addressing knowledge gaps in quality of milk for bulking purposes • Development of market for milk
Lead farmers	-	• Assisting in the identification of participating farmers, supporting farmer group formation • Uptake of and using demonstration technologies to cascade CSA production techniques to mentor 10 farmers each • Encouraging neighbouring farmers to adopt CSA production techniques • Selling silage to other farmers • CAHWs, working with agro-dealers for procurement of medicine for animal treatment kits, which was also a business
Extension Services	Ministry of Agriculture	• Participating in ToT and demonstration pilot activities

2.2.2 Model theory of change

How the model is designed to build resilience

Adequate good quality methane-reducing fodder production and supply

Support to increasing awareness and skills among dairy farmers and/or commercial fodder suppliers enabled increased and more reliable production of better quality and drought tolerant animal fodder. Awareness and skills development provided by government and other service providers, focused on cultivation and use of drought tolerant fodder seed varieties as well as improved production practices (e.g. intercropping) designed to maximise moisture utilisation and crop productivity. This was supported by increased farmer knowledge of good practices and better fodder utilisation. Improved animal nutrition resulting from better fodder use sought to enhance animal productivity, reduce methane emissions, resulting in a more sustainable smallholder dairy production system.

Climate-efficient milk handling and domestic technologies

To reduce methane production from manure, the project supported pilot investment in biogas digester units. The units were meant to enable farmers to process manure and reduce greenhouse gas emissions incentivised by the cost efficiency benefits of replacing wood fuel, which is not only costly but a driver of deforestation. In addition, the programme also piloted solar energy for milk cooling as alternative energy for the expensive, greenhouse gas emitting diesel or unreliable electric energy sources. In addition to reducing unwanted methane emissions, the utilisation of natural gas energy sources reduced household expenditure and raised net household incomes. Project investment in demonstration biogas units sought to showcase the benefits of these technologies and explore the cost benefit flows and viability for single and/or multiple household units.

Investment in the construction of (two) solar milk cooling systems (one Central and one South) provided the basis on which to prove and demonstrate the viability of group-run cost saving solar powered cooling services for MBG members. With access to more efficient and sustainable cooling facilities, smallholders are both incentivised and able to reduce milk spoilage and improve the quality of their off-take. In turn, higher traded volumes of better quality milk will enable MBG members to improve incomes from dairy production and provide the basis for downstream investment in improved breed, feed, and animal health care services and practices which, collectively, will improve animal productivity.

Productivity improvements through increased access to AI, extension, and veterinary services

The project promoted a number of significant investments in climate-smart production practices and infrastructure, from fodder to cooling and waste management. These investments sought to raise the prevailing smallholder dairy model in Malawi from an inherently low input, low output one to a more efficient, productive, and climate-smart model.

Complementing these investments will ensure sustained access to a more pluralistic extension and other key service provision model. The model sought to build the capacity for CSA extension and services targeting existing government extension service provision and resources, supplemented by private and civil society service providers. This approach sought to ensure the sustainability and outreach of extension provision through a cascade-oriented model of CSA practice and technology dissemination.

It is envisaged that the investments incumbent in the model(s) promoted will be supported by the enhanced incomes resulting from greater off-take and quality of milk and milk products sold in the market through MBGs and by individual producers. In addition, the reliability of production and improved quality of milk will further attract increased buyer and processor interest, investment, and price incentives.

Market development

The programme sought to build strong and sustainable market off-take arrangements through partnering with a milk processor and building quality assurance mechanisms and systems. In this regard, objective milk testing systems were put in place at 10 MBGs. This was achieved through the introduction of a milk hygiene premium scheme and building the capacity of smallholder farmers to improve hygienic milking and milk handling; and reducing milk adulteration. Given the protracted problem with respect to milk adulteration, the project realised that the problem was a mindset issue as opposed to a technical one and thus took a behaviour change approach to address the problem. At the factory level a laboratory was put in place for microbiological tests thus increasing scope for more complex milk testing procedures. As a result MBGs used milk analysers and milk adulteration kits and 24 behaviour change workshops reaching 4,208 farmers (1,881 women) were conducted.

2.2.3 How the model is designed for sustainability and scalability

The dairy model linked the private sector to farmers to ensure both sustainability and scalability. The private sector offers reliable marketing arrangements as well as access to training and other support services, which provide significant incentives for continued farmer participation. Moreover, the partnership realises that continued existence is reliant on mutual benefits run on win-win arrangements.

On the extension side, the model sought to ensure sustainability by working with the government extension services (Box 3).

This model has not only made it sustainable but complemented the lean government extension structure hence supporting the growing numbers of dairy animals in the various districts.

In Malawi, the government adopted a policy to promote a pluralistic and demand-driven extension system in 2001, officially allowing NGO and private sector involvement in the provision of agricultural extension. At the district level, the DAESS is the main framework for organising farmer demand through stakeholder panels and coordinating service delivery through extension coordination committees. At the national level, coordinating structures were largely absent until stakeholders established the Malawi Forum of Agricultural Advisory Services (MFAAS) in 2011 to serve as an information sharing body concerned with coordination, standardisation, quality, and capacity building.

Capacity development in CSA was targeted at the government extension service providers as well as other existing service providers. This was meant to build on outreach capacity and cascading of CSA practices and technologies. The government has front line extension officers at EPA level called AVOs who are responsible for offering extension services in livestock, particularly veterinary services. It should be noted that vets are not many in Malawi, such that most of the AVOs were not properly trained in school but rather on the job. No formal training institution provided training in veterinary studies especially at degree level. Most of the vets in Malawi were trained within the Southern Africa region until four years ago when the programme was introduced at LUANAR.

This coupled with the low extension officer to farmer ratio that dwindled from 1:750 in the 80s to 90s to 1:3900 to date, implies that one would rarely find livestock technicians in the villages. With most of the development projects, organizations place their own technical experts who in turn work with the government front line staff to build their capacity and sustain the services. Furthermore, MMPA has promoted training of farmer livestock technicians who are mainly trained in administering drugs to livestock, conducting pregnancy diagnosis, handling minor treatments and also conducting AI activities.

Box 3:. Malawi Government Extension Services

3 Assessing the success of the innovation model

3.1 Model success in delivering intended support services

The '*Building Climate Resilience for Dairy Farmers through Climate Smart Solutions*' project was successful in implementing the intended interventions despite the short timeframe. Training on fodder supply interventions such as hydroponic systems, legume-maize intercrops and fodder tree species were successfully conducted in all the 10 MBGs targeted by the project. Demonstrations to showcase the practices were also established at 16 households to expose farmers to the practices. Similarly, capacity building on milk hygiene and animal husbandry to improve feed formulations, feed preservation and animal housing, were conducted successfully for farmers in all the 10 MBGs. Specialised training on conducting vaccinations and administering AI were also offered to Community-based Animal Health Workers (CAHWs) and paravets in the area covered by the 10 MBGs to improve the quality of their services to farmers. These service providers were also equipped with start-up kits to enable them to set up a commercially sustainable service for farmers. The use of solar power for milk coolers was illustrated at two MBGs (Chonde and Magomero), while and biogas technology for domestic heating and cooking was showcased with two installations for farmers under Chizunga and Dzaonewekha MBGs.

At both the factory (Lilongwe Dairy) and MBG level, changes to milk quality assurance testing were implemented as planned. A microbiological testing laboratory was installed at Lilongwe Dairy to increase scope for more complex milk testing procedures. MBGs were also equipped with milk analysers and milk adulteration kits for on-going tests. By the time of the study, 24 behaviour change workshops reaching 4,208 farmers (1,881 women) had been conducted to influence farmers' mind set on milk handling and hygiene.

3.2 Signs of model impact on sensitivity and adaptive capacity of farmers and other market players

3.2.1 Changes in level of sensitivity of current production/market systems

Although it's still too early to assess changes in the sensitivity of production systems as a result to the project, some of the interventions, farmers indicated that there is already driving notable positive changes. For example, the green houses for hydroponic fodder introduced by the project are producing more than 4 kilograms of fresh fodder per day[9]. Since hydroponic fodder is fed as an additional feed (supplement), farmers are advised to feed 2 trays per cow per day. A dairy cow is recommended a minimum supplement of 2 kilograms per day for milk production. The hydroponic fodder is for supplementation only, meaning farmers still have to rely on other feeds for body maintenance (e.g. hay, silage, concentrates, and crop residues). In terms of nutrients, the fodder roots are rich in minerals, the stem and leaves are rich in energy, proteins and fibre which is good for improving rumination[10]. Farmers have reported increases in milk yields of up to six litres per cow per day, which represents a 75% increase from baseline average yields of 8 litres per cow per day.

3.2.2 Institutional changes as a result of innovation model

Notable institutional changes that were brought by the project include changes within the MBGs, MMPA and Lilongwe Dairy to improve milk quality assurance. These changes include the installation of factory level laboratory facilities to enable more complex milk testing procedures and milk testing kits at MBGs for daily quality checks. As a result of improved quality assurance checks, Total Bacterial Count (TBC) in the milk for farmers in the programme dropped from averages of around 33 million colony forming units per millilitre at the start of the intervention in August 2017 to 5 million colony forming units per millilitre by December 2017.

3.3 Local sentiment and perspective on the success of the innovation model

Although farmers were positive about some of the project interventions, they were equally sceptical about the feasibility of others within their system. For instance, the benefits of using hydroponic fodder production systems were

9. The green houses introduced by the project for hydroponic fodder production accommodates 35 trays. Each tray is planted with about one kilogram of seed (depending on seed type) and produces 2-3 kilograms of fresh green fodder after 12 days.
10. The microbes in the cow's rumen that help with digestion need a certain minimum amount of protein content in the diet to stimulate their proper functioning and efficient utilisation of feed.

acknowledged but farmers expressed concern on the difficulty of reaching sufficient scale to eliminate the need to travel far to collect fodder for their animals. Scale is constrained by the level of initial investment required to set up the infrastructure. The technology was however perceived to be simple and appropriate for smallholder farmers operating on small land holdings.

With respect to the biogas unit, both farmers and field staff on the project felt that the installation cost (MK 1,576,000.00)[11] is prohibitive for most households despite the significant benefits. Female household members expressed appreciation for the labour saving associated with reduced need to fetch firewood, the freeing up of time for other domestic chores and general improvements in quality of life. The bio-slurry from a biogas digester was also confirmed to be a good, odourless form of manure which is suitable for a variety of uses[12].

Figure 4:. Biogas Unit for clean energy

As in the case with biogas units, the concept of solar powered milk cooling innovation (Figure 6) was widely embraced by both farmers and field staff given significant reduction in operating costs and the avoided milk losses due to stable power supply. The upfront cost of the investment was however sighted as a major hindrance to adoption. Given that the benefits are spread over a long timeframe, farmers and field practitioners expressed the need for affordable finance to offset the high upfront costs.

11. Equivalent to US$ 2,188 at the time of the study
12. Bio-slurry is well treated compost manure and this substrate is a valuable soil fertilizer which is rich in nitrogen, phosphorus, potassium, and micronutrients, which can be applied on soils as either a liquid manure or dried manure. Compared to raw animal manure, digested sludge has improved fertilizer efficiency due to higher homogeneity and nutrient availability, better carbon nitrogen (C/N) ratio and significantly reduced odours. Storage and application of liquid manure, animal dung, and many organic wastes are sources of unpleasant odours and attract flies. The process of anaerobic digestion reduces these odours by up to 80 percent. The digested sludge is almost odourless after anaerobic digestion.

Figure 5:. Solar powered MBG milk cooling facility

As with other technologies, the project promotion of hydroponic technology has been received with scepticism by many farmers. Not only is the upfront investment significant, it also only offers scope for fodder supplementation. Producers remain reliant on other fodder sources for the bulk of their fodder requirements. Both farmers and some practitioners question the viability of this technology and engagement during the pilot has been largely in terms of partner farmers working 'on behalf of the programme' rather than adopting the technology as their own. Most farmers do not adhere[13] to the required protocol and thus fail to realise the potential benefits. This demonstrates the need for close monitoring and mentoring as well as providing evidence of demonstrated outcomes.

Figure 6:. Hydroponic Fodder Unit

13. Instead of the recommended 35 trays most farmers use below 20 trays thus making it difficult to match the cycle and number of trays recommended per animal

4 Assessing model adaptation and potential for sustainability

4.1 Extent of model adoption

The 'Building Climate Resilience for Dairy Farmers Through Climate Smart Solutions' project is still in the pilot phase but stakeholders are already taking a keen interest in assessing the merits and demerits of the model in driving dairy development in Malawi. The green energy interventions have a high potential for adoption with solar energy for milk cooling systems bringing relief to the MBGs. This is so because of current unreliable and costly power supply arrangements. The maintenance costs for the unit are lower than the diesel generator running and repair costs thus ensuring that MBGs can run the unit on their own after installation. The indications to date show that solar cooling is taking far less time and is more reliable as compared to the conventional use of diesel powered generators.[14] However, the upfront investment cost remains a major hindrance to MBGs thus pointing to the need for putting in place financing arrangements. As the cost of solar technology continues to decline, the adoption of this technology is set to increase.

To date, no biogas units have been constructed by independent households due to entry barriers with respect to cost of installation. The introduction of biogas digesters by Netherlands Development Organisation (SNV), in Zimbabwe reveals that building the capacity at local level through the training of biogas masons (builders) to construct biogas digesters, drastically reduces installation costs of biogas units. The SNV intervention reduced the installation cost for the unit from about US$2500 to US$600 as of 2013 and this cost could have continued to decline as the number of trained service providers increased over the years. The *Building Climate Resilience for Dairy Farmers through Climate Smart Solutions* project can draw lessons from this initiative in Zimbabwe. Because of the benefits of cooking and lighting with biogas, the programme has improved the lives of many rural households. However, assumptions about increased supply reducing installation costs remain impossible to validate given how nascent the market for digesters is. The SNV project has since introduced new appliances on the market, which are currently being tested, including refrigerators, rice cookers, geysers, and heaters that operate on biogas. These developments will potentially transform lives and ease the burden of women in particular.

"The good thing about this fire from a bio digester is that, it cooks fast when cooking food or boiling water. The fire is so strong such that I have to be there to avoid burning my food especially potatoes and rice. In terms of workload, it has been significantly reduced. In the past I used to go very far to fetch firewood, which I had to buy, like MK1,500 to MK2,000 for a bundle. I would use about 2 bundles in a week."

Mrs. D Nkankuni Mkaombe Village, Thyolo District

Although hydroponic fodder production is equally a new technology for most famers, there are early signs of adoption. MMPA has introduced the technology to 16 farmers in the Central and Southern regions of Malawi (6 Females, 10 Males). Persuaded by the increased milk yields that these farmers have realized, 100 farmers in four MBGs have already requested greenhouse paper sheet to buy under a revolving fund facility. Two farmers under Dzaonewekha and Bua MBGs have already acquired greenhouse paper through their MBGs and they are constructing their structures. Most farmers are requesting the greenhouse paper only because other materials are locally available e.g. poles and trays.

The major issue in respect of hydroponics fodder production systems seems to stem from the fact that there is no demonstrated impact with respect to the profits given the short duration of the project. However, given the fact that this technology has been proven in intensive high-tech production systems for ruminants particularly under land constrained

14. MMPA

farming systems, provides optimism for both vertical and horizontal scaling. Some of the host farmers seemed to be practising for the project rather than for their felt needs as most of them were utilising 50% and below of available capacity of the units, mainly due to lack of seed. This makes it difficult to realise the full potential of the technology thus increasing the risk of discontinued use of the technology post-Vuna. However, it was interesting that one of the farmers was experimenting with pigeon pea under the system - a sign of both innovation and buy-in. Such farmers are likely to continue with the system once they establish relevance. It was clear that feed from hydroponic systems is not meant to replace grass and hay fetched from the gardens but rather complementing the current source of feed. In that case, either this would reduce frequency of collecting grass but achieving more yield than before. A costing of the innovation is the key for replication purposes. Farmers need to contribute to instil ownership.

4.2.1 Institutional changes as a result of innovation model

Given the short implementation timeframe of the interventions in Malawi, not many cases of adaptation were evident. The only reported case of model adaptation relates to farmer driven innovations in the use of hydroponic fodder production systems where farmers are now experimenting with seed from different crops to assess their suitability. Seed in a major input in the hydroponic fodder system and both its limited availability and cost are major constraints faced by farmers. By using a wide variety of seed, being more flexible and adaptable on what to use, farmers are better able to manage the costs and consistency in the use of the technology.

4.2 Model's commercial viability

The commercial viability of the various technologies piloted under this project is not clear at this stage due to the short implementation timeframe. However, emerging signs are that;

1. Hydroponic fodder production

According to little data that has been collected, hydroponic fodder has increased milk production by about six litres per cow per day, which translates to about a 75% increase from initial average milk yields of around 8 litres per cow per day. These increases were reported to be quite stable as they can be sustained for up to two weeks after the withdrawal of the fodder ration. This is a sharp contrast to conventional dairy marsh ration which results in instant drop in milk yield once its use is discontinued. Given the minimal input costs and little labour input, the use of hydroponic fodder systems seems financially viable. In addition, the upfront investment costs are affordable as demonstrated by nearly 100 farmers who have used their own resources to purchase the plastic for the greenhouse which is the main external resource needed as all the other materials are locally available.

2. Solar milk cooling systems

The pilot has demonstrated that the maintenance costs for the units are much lower than the diesel generator running and repair costs. This suggests that MBGs can run the unit on their own once installation is complete. Nevertheless, the upfront investment is significant, and availability of materials and specialist installation skills is a concern for the use of this technology. Farmers cited the initial investment as prohibitive irrespective of the long term cost savings. An economic analysis is required to establish the economic benefit and the appropriate financing arrangements for this type of investment.

3. Biogas digester

A comparison of the discounted costs of a biogas unit over the 25 years of guaranteed lifespan and costs related to firewood purchases (MK 3000/week which translates to a payback period of just over 9 years) over the same period reveal the added value for such an investment. Nevertheless, long cost-recovery periods are widely accepted as unattractive for many private investments in most sectors and the Malawi smallholder dairy sector is not an exception. The cost benefit analysis of using the 8-cubic metre biogas digester reveals that an average household of six people uses about 7 kilograms of firewood a day, translating to about 2.6 tonnes of firewood per year[15]. Currently one family is utilizing the gas from the digester although there is a provision for the digester to be connected to two more households resulting in much higher savings on firewood. The biogas digester that was constructed by the project have a lifespan of up to 40 years with good management practice because it has a double layer of bricks throughout[16]. The payback period of the investment is about five years when compared to a family household that uses electricity for cooking. Return on investment and the payback period could be improved if such installations are modified to cater for more than one household per each installation. This, however, significantly increases the challenges of managing collective investments and poses an entirely new set of risks to sustainability.

4.3 Expansion and wider adoption and benefits

Even with the short timeframe of project implementation, some of the interventions have shown potential for wider adoption and expansion. The adoption of hydroponics in fodder production and the use of AI in breeding are such examples. Wider adoption of technologies such as biogas digester units and solar milk coolers will depend on availability of financing to cover upfront costs. There is also scope for financing of solar cooling facilities by the private sector partners such as in by the private sector partners such as Lilongwe Dairy as they stand to benefit from improved milk quality and reduced wastage.

The demand by for breed improvement and animal health support services (AI and veterinary services) is already high and is like to continue rising as the benefits become apparent. Project trained MBG based service providers (paravets and inseminators) are preferred over independent service providers who charge higher fees and require upfront payments. Project trained service providers allow a payment plan for farmers with fees being deducted from milk sales at the end of the month. Continued demand for such services is however dependent on good performance by the MBG based service providers in respect of professional conduct, integrity, and delivery of intended results.

5 Findings and lessons for model improvement

Emerging lessons from the Malawi dairy sector innovation case with regards model development and implementation are outlined below:

Clarity of model, goals, and objectives: The initial conceptualisation of the project (according to application documents) emphasised climate smart fodder production and extension and methane-reducing manure management technologies. In practice, the scope of the programme extended into a range of interventions, not all of which linked directly to dairy production. Focus shifted from improving prevailing fodder cultivation practices to introducing hydroponic technologies, and the interventions expanded to include solar energy technologies, water harvesting practices, AI, and breeding services.

This approach has resulted in a loss of focus on individual innovations, the rationale behind them and subsequent quality of partnerships and performance. The expanding scope of activities has contributed to an increasingly technology driven set of activities and a move away from the objective of developing and innovating around service and delivery models.

15. Other hidden costs associated with the use of firewood such as the risk of respiratory diseases due to indoor air pollution have not been considered as they typically do not influence decision making.
16. For single brick layer digesters the, life span is around 20-25 years. The likelihood of developing cracks is however higher for single layer digesters due to low mechanical strength.

That this 'mission creep' has been possible also points to weaknesses in measurement, monitoring, and management within and beyond the programme's design. Poorly defined innovation focus and objectives may also be expected to render tight monitoring of progress and performance problematic.

Lesson: In seeking to change prevailing practices, it is important that the change, or 'innovation' is clearly defined and understood by partners and its uptake and measurement tightly monitored and measured.

Analysis-led model design: While the original conceptualisation of the project suggests clear constraints it sought to address, this did not always correspond with actual interventions. For example, analysis of fodder related issues highlighted the need for large quantities of better quality, drought resistant fodder potentially under commercial production systems. It is not clear how the subsequent hydroponics technology addresses these identified constraints.

Lesson: Relevant practice or service innovations are those based on clear and rigorous analysis of constraints. This maximises the likelihood of partner buy-in and uptake, but also ensure that technologies or other interventions address the root cause of problems to which they are intended.

Contextualising the innovation landscape: In light of the disappointing feedback on different technologies introduced, it is unclear to what extent the project undertook rigorous analysis of the utility and performance of those technologies elsewhere. In particular, there is significant experience of biogas digesters and hydroponic technologies to question their commercial viability or indeed technical relevance to a system such as smallholder dairy production in Malawi. It remains unclear the degree to which wider experience and consultation informed project design.

Lesson: The introduction of appropriate technologies and innovation requires understanding of the wider innovation landscape and lesson learning, as appropriate, from similar systems and/or initiatives.

Building a robust business case for model: A key objective for piloting new practices or technologies is that of proving the viability and rationale for those innovations. A clear business case remains unproven for all the core technologies under this project and it is unclear if the monitoring framework is sufficient to generate the data that would be required to establish such a business case. Consequently, scepticism among primary beneficiaries remains and can be expected to limit wider uptake and innovation sustainability.

Lesson: A primary objective of any pilot of a new practice or innovation is to establish and/or prove a clear and valid business case necessary to underpin uptake and sustainability. Effective measurement frameworks are a pre-requisite to capturing and documenting that business case.

Building reciprocal partnerships: The case suggests that in many of the activities, the project fully-funded initial investment, supporting services and other costs associated with the models introduced. In none of the interventions has there been substantive reciprocal investment by beneficiaries or partners. This approach has, inevitably, reduced the degree of ownership and uptake observed among beneficiaries.

Lesson: The long term sustainability and scale of wider uptake of any new practice or technologies requires that beneficiaries recognise and increasingly shoulder a significant (and, ultimately, all) proportion of the costs of those practice changes.

ANNEX 1:

Climate trends and risks for dairy framing in Malawi

Extreme weather events

An observation of drought events in Malawi over a period of 20 years (from 1980-2000) indicates widespread incidents across the country as illustrated in Figure 1 (middle), with 10 drought incidents recorded in the Southern province. The other provinces had incidents ranging from approximately four (lowest) to eight. In terms of flooding (Figure 1, right), the Southern province of Malawi experienced the highest incidence with a reoccurrence of seven events. The rest of the country has incidents ranging from one (in the Central province) to approximately five in both the Southern and Northern provinces. Similarly, to other countries in the region, some of the flood events are influenced by cyclones such as Cyclone Eline in 2000 and Cyclone Dineo in 2017. The impacts of flooding on economic activities are substantial, for example in 2015, the projected gross domestic product (GDP) of the country was revised from 5.1% to 3.1%.[17]

A historical assessment of temperature change in the past 37 years (Figure 1, left) highlights an increased warming trend. The highest temperature change is observed in the Southern province with a change of 0.57-0.68°C. Areas in the Central as well as the Northern provinces including the areas where the dairy projects are located experienced moderate

Quick facts:

Climate Change Trends in Malawi

Rainfall

- Northern Malawi anticipate reduced rainfall associated with the late onset of the farming season2
- Earlier rainfall season, increases in the length of the mean dry spell and a reduction in the rain day frequency are expected.
- Average rainfall projections, for the period 2010 to 2075 show a 4.7-0.7% reduction across the country in yearly averages. Southern Malawi will be worst affected

Temperature

- Projected increases in temperature of approximately 1.75-3°C by the year 2050, with wide range increases from 0.75° to a maximum of 3.5° across the country are anticipated4.
- Using past climate, variability reveal that there will be significant increases in temperatures across the country, ranging from 19-27°C in areas around Dedza district.

Extreme Weather Events

- Drought events are expected to increase in the region including in Malawi
- Increases in flooding events are expected due the increase in cyclones and tropical storms. These events are expected to increase in frequency and intensity.
- Extreme high temperatures resulting in hot days and heat waves are also expected.

17. Malawi Government, 2016

temperature change of between 0.42-0.53°C, over the 18-year period from 1985-2003.

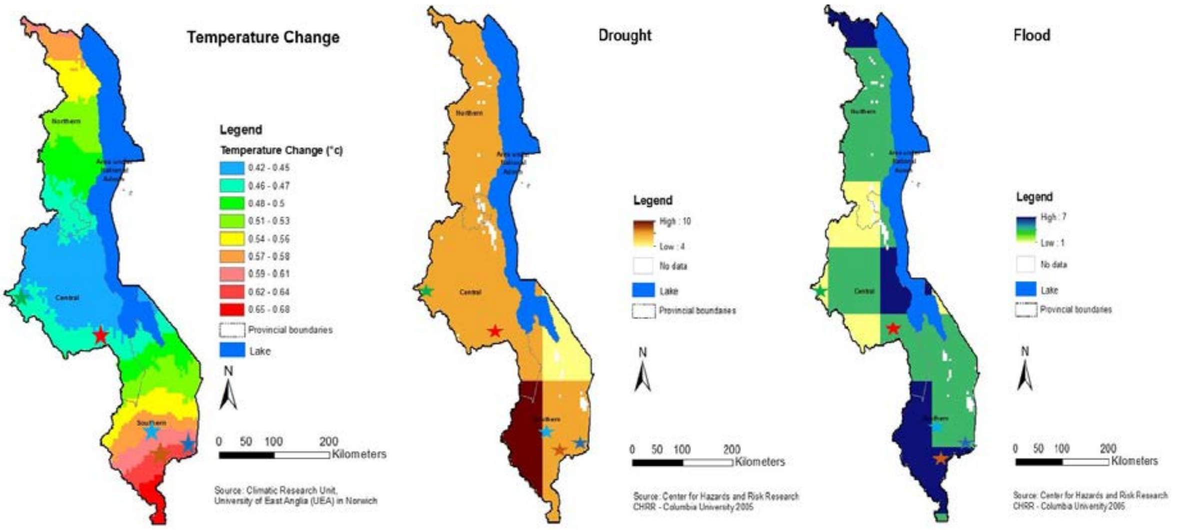


Figure 7:. Temperature change (left) drought (middle) and flood (right) in Malawi. The project sites are marked by the starts. Green – Mchinji (1 MBG), Red – Dedza (3 MBGs), Light Blue – Chiradzulu (1 MBG), Dark Blue - Mulange (1MBG) and Orange – Thyolo (4 MBGs).

Impacts of rainfall changes on dairy farming

The projected changes in rainfall as well as the changes in the timing of the rainy season will affect all agricultural activities including livestock. Southern Malawi will be the worst affected by the temperature change, while the changes will be moderate in Northern Malawi.[19] Rainfall variability will affect rangelands and pastures, with detrimental impacts on feed grains as well as fodder production. Rainfall variability further exacerbates water availability and this negatively impacts on milk production.[20]

Impacts of temperature changes on dairy farming

Temperature increase will affect dairy cows in particular milk production and reproduction rates. Depending on the breed of the cows, in general, temperatures below 21°C are considered good, while temperatures above 21°C are considered marginally extreme for milk production.[22] High temperatures resulting in warmer and drier conditions will increase the probability of heat stress leading to reduced milk production in dairy cows by as much as 20%, while conception will be affected by approximately 35%.[23]

Impacts of extreme weather events on dairy farming

Climate change, both temperature and rainfall variability, will exacerbate livestock diseases and parasites, resulting in negative impacts for dairy production. Despite the reduction in average annual rainfall, the intensity and frequency of

18. Tadross *et al*., 2007
19. Malawi Government, 2011
20. Siemes, 2000 in Kasulo *et al*., 2016
21. Ardnt *et al*., 2014
22. Igono *et al*., 1998
23. Klinedinst *et al*., 1993 and Nesamvuni *et al*., 2012

flooding events will result in intense rainfall distribution across all the provinces from 2041-2050.[24] Heat stress as a result of extreme high temperatures will consequently affect dairy production and may even lead to the death of animals.[25] However, in areas such as Dedza, the impact of temperature increase on dairy production should be marginal. As a result of the expected increases in temperature and rainfall variability in intensity and frequency, as well as the projected increase drought and floods, breeding goals may have to be reviewed to account for higher temperatures, lower quality diets and greater disease challenges. Therefore, breeds that are well adapted to such conditions may become more widely used.

24. Arndt *et al*., 2014
25. Nesamvuni *et al*., 2016

ANNEX 2:

Project interventions by MBG

MBG	District	Region	Technologies
Chizunga	Thyolo	South	Hydroponics, Biogas, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings (feed formulaiton, feed preservation and animal housing), agribusiness training, CAHWs.
Chonde	Mulanje	South	Solar, Water harvesting, AI and Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings, agribusiness training, CAHWs.
Matapwata		South	Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings, agribusiness training, CAHWs.
Namahoya	Thyolo	South	Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings (feed formulation, feed preservation and animal housing), agribusiness training, CAHWs.
Thunga	Thyolo	South	Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings, agribusiness training, CAHWs.
Namitembe		South	Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings, agribusiness training, CAHWs.
Bua	Mchinji	Centre	Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings (feed formulation, feed preservation and animal housing), agribusiness training, CAHWs.
Chitsanzo	Dedza	Centre	Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings (feed formulation, feed preservation and animal housing), agribusiness training, CAHWs.
Dzaonewekha	Dedza	Centre	Biogas, Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees, Vaccination, AI, Animal husbandry trainings (feed formulation, feed preservation and animal housing), agribusiness training, CAHWs.
Magomero	Dedza	Centre	solar for cooling tanks, Hydroponics, revolving funds, intercropping legumes with maize, Demo plots for fodder trees and Rhodes grass, Vaccination, AI, Animal husbandry trainings (feed formulation, feed preservation and animal housing), agribusiness training, CAHWs.

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