The Government of The Kingdom of Lesotho

Technology Needs Assessment for Climate Change Adaptation in the Agriculture and Water Sector

September 2023

Ministry of Defence, National Security and Environment

Technology Needs Assessment for Climate Change Adaptation in Agriculture and Water Sectors

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To be cited as

Government of Lesotho, 2023. Lesotho Technology Needs Assessment Report – Adaptation (Agriculture and Water Sectors). Ministry of Defence, National Security and Environment. Maseru, Lesotho.

This publication is an output of the Technology Needs Assessment (TNA) project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP Copenhagen Climate Centre (UNEP CCC, formerly UNEP DTU Partnership) in collaboration with the University of Cape Town. The views expressed in this publication are those of the authors and do not necessarily reflect the views of UNEP CCC, UNEP or the University of Cape Town. We regret any errors or omissions that may have been unwittingly made. This publication may be reproduced in whole or in part and in any form for educational or non-profit services without special permission from the copyright holder, provided acknowledgement of the source is made. No use of this publication may be made for resale or any other commercial purpose whatsoever without prior permission in writing from the UNEP CCC and Ministry of Defence, National Security and Environment of the Government of the Kingdom of Lesotho.

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Foreword

Climate variability and change have become major threats to sustainable development in Lesotho. Over the last few decades, the country has experienced an increase in magnitude of climate-induced hazards such as droughts, floods, heavy snowfall and extreme temperatures. These adversities tremendously impact sustainable livelihoods, security and well-being of society and contribute to increased incidences of poverty and undue pressures on social services. In order to tackle such climate change threats in a systematic manner, the National Climate Change Policy (NCCP): 2017 – 2027 (LMS 2017) was formulated. The policy guides the integration and mainstreaming of climate change management in development planning and implementation by all stakeholders at local, district and national levels. The policy further creates an enabling framework for a pragmatic, coordinated and harmonised approach to climate change management.

Although Lesotho is an insignificant contributor to global greenhouse gas (GHG) emissions, it is among the countries that are and will continue to be severely impacted by climate change. The country has thus committed itself to developing, adopting and implementing policies and measures that will assist it to adapt and increase its resilience to the adverse impacts of climate change. Lesotho is committed to national strategies in line with the National Adaptation Plan of Action 2007; 2nd Five-Year National Strategic Development Plan (NSDP II), 2018/19 – 2022/23; Climate Smart Agriculture Investment Plan 2018; the National Climate Change Policy 2017-2027; the nationally determined contribution (NDC) 2017 commitments under the 2015 Paris Agreement and the NCCP and strategic national policies.

Urgent climate action is imperative for Lesotho to achieve its development aspirations. However, this is hindered by slow technological mobilisation coupled with inadequate knowledge transfer and limited financial capacity, all of which exacerbate systemic failures in addressing key drivers of climate vulnerability and inaction. This Technology Needs Assessment (TNA) process is therefore fundamental in helping to bridge this gap and ascertain the technological needs for transformative climate adaptation and mitigation initiatives at the national and sub-national levels.

In this regard, the Lesotho’s TNA has been developed through extensive stakeholder engagements with Government agencies, private sector, financial institutions, academia, project developers and local technology experts, ensuring gender inclusion at all stages.

Executive Summary

A Technology Needs Assessment (TNA) is a set of activities that identify and analyse technology priorities for mitigation and adaptation of developing countries such as the Kingdom of Lesotho. This project has allowed Lesotho to identify climate technology pathways that assist in the implementation of the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC). The process is country-driven, based on stakeholder engagement and local capacity building. The scope and depth of this TNA is well aligned to our national development objectives and allows national stakeholders to explore synergies with other national processes, striving towards the implementation of Nationally Determined Contributions and National Adaptation Plans. The TNA is entailed in a three-stage process and has three key objectives: a) To identify and prioritise mitigation and adaptation technologies for selected sectors; b) To identify, analyse and address barriers hindering the deployment and diffusion of the prioritised technologies, including the enabling framework for these technologies; c) To conduct a Technology Action Plan, which is a medium/long-term plan for increasing the implementation of identified technologies, based on the inputs obtained from the previous two steps. The Technology Action Plan outlines actions to be undertaken. Lesotho's TNA is focused on agriculture and water resources as priority sectors under the adaptation component of the project. On the mitigation side, the sectors selected to undergo a needs assessment were Agriculture, Forestry and Land Use (AFOLU) and Energy. The choice of sectors selected for assessment was informed by national policies and selected by the technical team through a series of stakeholder consultations in collaboration with the Lesotho Meteorological Services and the National Climate Change Committee within the context of the Climate Change Policy. The foregoing authorities have the responsibility of mainstreaming development in Lesotho that is related to climate change mitigation and adaptation. As part of this first deliverable of the three in this process, the national consultants prepared technology factsheets (TFS) for several technologies with the assistance of sectoral experts. Technologies were streamlined by the technical working group before being presented before a wider national stakeholder audience. Three technologies prioritised under each sector underwent a thorough selection and scoring process. This selection process was referred to as the Multiple Criteria Analysis (MCA). The MCA is an 8-step process involving: i) providing decision context on the sectors; ii) identifying technologies; iii) identifying objectives and criteria; iv) scoring; v) weighting of criteria; vi) combing scores and weights; vii) examination and validation of results; and viii) sensitivity analysis based on the social, economic and environmental aspects needed for the successful implementation of the technology. To validate the results, the outcomes of the MCA underwent a sensitivity analysis repeating steps 4 to 7 of the MCA.

Lesotho's contribution to global greenhouse gas emissions is insignificant in comparison to its level of vulnerability due to climate change. Some of the key key challenges of the Mountain Kingdom include food insecurity associated with high levels of soil erosion and land degradation and energy challenges especially for Basotho living in remote mountain communities. Hence the choice of sectors for our TNA: agriculture and water. A comprehensive stakeholder engagement process was required to undertake the country driven technology needs assessment. The heart of this stakeholder engagement process lay in bilateral between stakeholders on the TFS, email exchanges, and workshops to enhance understanding and transfer vital information about the sector plans and priorities. While the comprehensive reports on the TNA for mitigation and adaptation have been presented as two separate reports, this summary will shed light on the technologies that have been prioritised by the people of Lesotho. The technologies will contribute to and enhance the Government of Lesotho's ongoing efforts in ensuring a resilient and low-carbon economy. To address the vulnerability areas under the Climate Vulnerability Assessment and achieve the adaptation goals, national stakeholders prioritised decentralized community-run early warning system, rainwater harvesting, and conservation agriculture for making a resilient agricultural sector. Similarly, the technologies prioritised for the water sector: 1) Water reuse, 2) Rainwater collection from ground water surfaces; and 3) Boreholes as a drought intervention for domestic water supply. : The results and outcomes from the prioritisation exercise will next undergo a barrier assessment in the implementation of prioritised technologies and the preparation of technology action plans for the deployment of these technologies.

List of Acronyms

CO_2	Carbon dioxide
CSA	Climate Smart Agriculture
CSAIP	Climate Smart Agriculture Investment Plan
EWS	Early Warning System
FFS	Farmers Field Schools
GDP	Gross Domestic Product
GHG	Greenhouse gas
GHGs	Greenhouse gases
GOL	Government of Lesotho
HWTS	Household Water Treatment and Safe Storage
ICM	Integrated Catchment Management
INC	Initial National Communication
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
ISNM	Integrated Soil Nutrient Management
KPA	Key Priority Area
LGBTQ+	Lesbian, Gay, Bisexual, Transgender and Queer (or questioning) and others
LHDP	Lesotho Highlands Development Project
L-IB-NAIP	Lesotho Instrument Based National Agriculture Investment Plan
LMS	Lesotho Meteorological Services
MCA	Multi Criteria Analysis
MDGs	Millennium Development Goals
MEM	Ministry of Energy and Meteorology
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NCCP	National Climate Change Policy
NDC	Nationally Determined Contribution
NGOs	Non-Governmental Organisations
NSDP II	Second National Strategic Development Plan
NUL	National University of Lesotho

RCP	Representative Concentration Pathway
SDGs	Sustainable Development Goals
SNC	Second National Communication
SPEI	Standardized Precipitation-Evapotranspiration Index
SRB	Senqu River Basin
SRV	Senqu River Valley
TAP	Technology Action Plan
TFS	Technology Factsheets
TNA	Technology Needs Assessment
TNC	Third National Communication
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WAMPP	Wool and Mohair Promotion Project
WBG	World Bank Group

Chapter 1 Introduction

1.1. About the TNA project

Adaptation is an essential element of human response to climate change. The adverse impacts of climate change on the different economic and livelihood sectors are now palpable worldwide and are projected to be the most severe in resource-poor countries. Therefore, it is necessary to access and adopt a diverse array of adaptation technologies and practices that are appropriate and affordable in local contexts. The scale of these adaptation technologies/practices should ideally range from the individual household level (e.g. adoption of climate smart agriculture practices at household level) to the community landscape scale (e.g. climate rangeland management practices on common property landscapes) to large scale national and /or private sector e.g. waste management facilities.

The goal of this Technology Needs Assessment (TNA) process is to identify and prioritize technologies for adaptation and mitigation. This process seeks to increase the diffusion and deployment of key technologies that are presently being under-used, but which can have important future contributions to the country's climate change programme, as well as contributing to the SDGs and national development. Thus, in this national context, TNA is a set of country-driven activities that identify and determine the adaptation and mitigation technology priorities of the Kingdom of Lesotho to climate change. Thus, the TNA presents an opportunity to track evolving needs for new equipment, techniques, services, capacities and skills necessary to mitigate greenhouse gases (GHGs) emissions and reduce the vulnerability of key economic sectors and livelihoods to climate change. The objective of the assessment is to prioritize technologies for adaptation considering national development objectives and to explore how this could be fed into strategic development plans such as the Second National Strategic Development Planning (NSDP II, 2018/19 – 2022/23) as extended, and the Nationally Determined Contribution (NDC). In this assessment, we first identify development priorities and use them as criteria for selecting strategic sectors for adaptation. Subsequently, we seek to identify and prioritize relevant technologies for the respective sectors. We then identify barriers hindering acquisition, deployment, and diffusion of prioritized technologies. Finally, we undertake to develop a Technology Action Plan (TAP) specifying activities and enabling frameworks to overcome the barriers and thereby facilitating transfer, adoption and diffusion of the selected technologies.

TNAs are central to the work of Parties to the Convention on technology transfer and present an opportunity to track evolving needs for new equipment, techniques, and practical knowledge and skills, which are necessary to mitigate greenhouse gas emissions and reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change. The enhancement of technology development, its transfer, deployment and dissemination is a key pillar of the international response to climate change. The scope and depth of the TNA is well aligned to national development objectives and allows national stakeholders to explore synergies with other national processes, striving towards the implementation of Lesotho's Nationally Determined Contributions and National Adaptation Plan. The TNA is a three-stage process and has three key objectives: a) To identify and prioritise mitigation and adaptation technologies for selected sectors; b) To identify, analyse and address barriers hindering the deployment and diffusion of the prioritised technologies, including the enabling framework for these technologies; c) To develop the Technology Assessment Plan (TAP), a medium/long term plan for increasing the implementation of identified technologies, based on the inputs obtained from the previous two steps. The TAP outlines actions to be undertaken.

1.2. Existing national policies related to technological innovation, adaptation to climate change and development priorities

The development priorities for Lesotho are derived from ongoing policies, strategies and plans, programmes and projects, long-term vision documents as well as strategies for climate change mitigation and adaptation.

1.2.1 The National Adaptation Plan of Action (NAPA 2007)

Climate change and development are intertwined especially in developing countries where development is strongly linked to natural resources and environmental conditions. In Lesotho, more than 80 percent of the population relies on natural resource-based livelihoods such as agriculture. This exposes the economy to environmental shocks such as natural disasters and the negative impacts of Climate Change. To this effect the country prepared an National Adaptation Programme of Action (NAPA) in 2007. The NAPA process identified eleven adaptation options outlined below in their order of priority (NAPA 2007):

- **Option 1:** Improve Resilience of Livestock Production Systems Under Extreme Climatic Conditions in Various Livelihood Zones in Lesotho
- **Option 2:** Promoting Sustainable Crop Based Livelihood Systems in Foothills, Lowlands and Senqu River Valley

- Option 3: Capacity Building and Policy Reform to Integrate Climate Change in Sectoral Development Plans
- Option 4: Improvement of an Early Warning System Against Climate Induced Disasters and Hazards
- **Option 5:** Securing Village Water Supply for Communities in the Southern Lowlands
- Option 6: Management and Reclamation of Degraded and Eroded Land in the Flood Prone Areas
- **Option 7:** Conservation and Rehabilitation of Degraded Wetlands in the Mountain Areas of Lesotho Option 8: Improvement of Community Food Security Through the Promotion of Food Processing and Preservation Technologies
- **Option 9:** Strengthening and stabilizing eco-tourism based rural livelihoods
- **Option 10:** Promote Wind, Solar and Biogas Energy Use as a Supplement to Hydropower Energy
- **Option 11:** Stabilizing Community Livelihoods which are Adversely Affected by Climate Change Through Improvement of Small-Scale Industries

This strategic document launched national activities to respond to climate change in a more systemic manner and sought to integrate climate change into sectoral development plans (NAPA - Option 3) as prelude to the development of the National Climate Change Policy 2017-2027 (NCCP). After the NAPA, all development policies sought to transform Lesotho’s economy from a lower-middle-income country with a low ranking to a middle-income status.

1.2.2 The National Strategic Development Plan II Strategic Focus: 23/24 – 27/28

Past and current Development Plans have been formulated to define a desired destination and identify the roles that different sectors of society need to play to realise a set goal. This requires critical levels of commitment and leadership to strengthen the planning systems within and across all the spheres of government, and collaboration of the private sector, civil society, and development partners. Lesotho’s planning and fiscal operations are guided by the national planning frameworks to promote sustainable development. However, the country remains vulnerable, with low investment in key areas, low productive capacity, and high-income inequality. The economy is still highly dependent on government for economic activities and fiscal revenues. Lesotho’s capacity to attract foreign investment is limited and the country remains very dependent on imports. Poverty and unemployment rate remain high, especially in the rural areas, affecting mostly women and youth. The Government of Lesotho has decided to extend the NSDP II: 2018/19 – 2022/23 by five years to ensure the effective implementation of policies and actions set out therein.

The Strategic Framework set out four key priority areas to develop and diversify Lesotho's economy. It outlines initiatives that focused on achieving increased and higher economic growth from both existing sectors of Lesotho's economy and those that are new and emerging. It sets in motion key objectives of the situational analysis and foundational work that were carried out in several areas and key economic sectors across the economy. It highlights the need to consider cross cutting issues such as environment and climate change, Youth, gender and emerging sectors such as digital technology and, renewable energy. It is, therefore, the purpose of this framework to set out a roadmap for achieving the rapid economic growth through adherence to the following key priority areas of sustainable development: Growth Progression (NSDP II Key Priority Area I identifying agriculture of as one of four engines of development), Social Transformation (NSDP II KPA II), Infrastructure Development (NSDPII KPA III), Good Governance and Accountability (NSDP II KPA IV). This strategy also contains cross cutting themes or topics such as Environment and Climate Change that are integral components of NSDP II, as the population relies heavily on climate vulnerable sectors such as agriculture, water resources and biodiversity.

1.2.3 The National Climate Change Policy (NCCP): 2017-2027

The National Climate Change Policy (NCCP): 2017-2027 (LMS 2017) sets the climate change agenda in Lesotho and articulates national aspirations on matters of climate mitigation and adaptation. To effectively implement the policy, a five-year National Climate Change Implementation Strategy (NCCPIS) has also been developed as an implementation framework of the NCCP. The strategy establishes action guidelines for mainstreaming climate change into key socio-economic sectoral plans and programs while safeguarding environmental integrity and sustainable development in Lesotho. The policy has 22 strategies to ensure that stakeholders address climate change impacts and their causes through identification, mainstreaming and implementation of adaptation and mitigation measures, while promoting sustainable development. The strategy identified action guidelines to build a climate resilient society and promote green development pathways by mainstreaming and integrating climate change into key national socio-economic and environmental sectors.

1.2.4 Nationally Determined Contribution

In the backdrop of the Lima Call for Climate Action (Decision 1/CP.20) in 2014, the Kingdom of Lesotho submitted her Nationally Determined Contributions (NDC) to the UNFCCC following a series of consultations on the nature of the national development trajectory between 2020 and 2030 and the potential greenhouse gas emissions published in 2015. However, it was then obvious that to achieve the NSDP's objectives, catch up on the backlog against the MDGs and to sustain poverty reduction, Lesotho needed to set minimum long-term economic growth threshold of at least five percent with the view to double approximately every 16 years (NSDP, 2012).

1.2.5 Agriculture development strategies and plans

The Lesotho Instrument Based National Agriculture Investment Plan (L-IB-NAIP) 2022-2026 aim is to ensure sustainable agriculture sector growth, decent jobs, and food and nutrition security for the Basotho people (NAIP 2022-2026). The Climate Smart Agriculture Investment Policy (CSAIP) (World Bank, 2019) further aims to ensure that agriculture contributes to the national objectives which include the increase in agricultural productivity and output which will enhance the sectors contribution to national economic growth.

Agriculture plays a significant role in the economy. The sector has been selected as one of four priority areas in the National Strategic Development Plan (NSDP) II due to its potential to reduce rural poverty, improve incomes, generate employment, and increase food security. Agriculture in Lesotho consists of field crops; horticultural crops, including fruits; livestock, including poultry, piggery, dairy cows, sheep, and goats. The sector sustains livelihoods of 71% of Lesotho population residing in the rural areas and directly generates employment for 41% of this population, although primarily on an informal basis, with women making up the largest share of the labour force (World Bank, 2020). In addition, agriculture also has a crucial social dimension because agricultural activity is pervasive as a safety net for much of the population. Notably, agriculture in Lesotho contributes about 19.9 percent GDP in the year 2020-21 from 17.8 percent in the year 2019-20 although the last time agriculture contributed about 20 percent of the GDP was in the year 2003-04 (NAIP 2022-2026).

The Lesotho Instrument-Based National Agricultural Investment Plan (L-IB-NAIP) Strategic framework consists of seven strategic axes which are informed by the findings from the Zero Hunger Strategic Review (ZHSR, 2018) and NSDP II are: (1) Enhancing the enabling capacity of the public sector; (2) Promoting the development of private sector-led Agri-food-systems;

(3) Enhancing the Business Environment for Priority Commodity Value Chains; (4) Developing Technology and Infrastructure; (5) State Support to Value Chain Players (Direct Transfer); (6) Emergency preparedness, nutrition, and social protection; and (7) Sustainable management of land, water and social protection.

In addition, it provides a road map for implementation of the Sustainable Development Goals (SDGs), the African Union Agenda 2063 Goals and the Southern African Development Community (SADC) Regional Indicative Strategic Development Plan (SADC RISDP). Thus, the NSDP II emphasises private sector development and gives priority to pursuing people-centred development. This strategy seeks to re-enforce the government of Lesotho's commitment to directly engage citizens, empower individuals, and encourage participation during the development process. This strategy has identified four key priority areas (KPAs) that are articulated to promote job creation and inclusive growth and further reduce poverty. The KPAs aim to enhance inclusive and sustainable economic growth and private sector-led job creation (KPA I), to strengthen labour capital (KPA II), to build enabling infrastructure (KPA III) and strengthen national governance (KPA IV). The aim of the first KPA is to promote/enhance inclusive and sustainable economic growth and private sector-led job creation. Through it, the NSDP II strives to secure jobs in the four productive sectors: agriculture, manufacturing, tourism and creative industries, and technology innovation. An expected outcome from a successful delivery of interventions under this KPA is a sustainable commercial agriculture and food security. Strategic documents in this regard include the Climate Smart Agriculture Investment Plan (2018).

The KPA II focuses mainly on strengthening human capital where the government of Lesotho will build human capabilities through investment in health, nutrition, education, and skills development. This strategy aims to support the productive sectors which will provide social protection to safeguard society against emerging vulnerabilities and other disasters. Successful delivery of interventions under this KPA will result in the following outcomes: Resilient health care systems, improved health care outcomes and reduced malnutrition. KPA III aims to build enabling infrastructure that the government of Lesotho has committed to provide as an incentive for private sector agents to invest in the economy. Infrastructure is expected to affect growth at least through two classic channels of drivers of economic growth: directly through capital accumulation and indirectly through raising total factor productivity gains. The expected outcome from a successful delivery of interventions under KPA III are as follows: sustainable quality transport network; sustainable production, use of water resources, and improved sanitation and hygiene; and improved quality of the built environment. KPA IV focuses on strengthening national governance and accountability systems whereby good governance, rule of law and credible leadership are critical elements in ensuring successful delivery of NSDP II.

1.3. Vulnerability assessment in the country

Lesotho increasingly experiences extreme weather events because of climate change. Prolonged dry spells, recurrent droughts, intense rainfall, localized floods, early and late snowfall, hailstorms and strong winds have all become more commonplace than in the past. Current projections indicate increasing temperatures, decreasing summer precipitation, increasing frequency of droughts, heavy rainfall, hailstorms, prolonged mid-season dry spells and the late start and early end of the rainy season will persist (LMS, 2010). The weather patterns will in turn increase the vulnerability of climate-sensitive sectors, including agriculture, forestry, water, livestock and health.

Climate models in the Lesotho Third National Communication to the Conference (TNC) of the Parties (LMS, 2018), project more frequent droughts and dry spells with erratic precipitation and high intensity torrential downpours with prolonged wet periods in the mid-term (2045-2070), and possibility of amplified drought in the long term (2071 – 2100). In the Southern Lowlands and Senqu River Valley livelihood zones, projections show compounded likelihood of intensified incidence of drought spells and incidence of heavy to extreme precipitation with potential flooding consequences. All these phenomena will increase the risk of soil erosion and vegetation damage through runoff. Overall, the models project decreasing precipitation falling erratically with high intensity storms.

The causal factors of the vulnerability of Lesotho’s population, particularly those in southern lowlands and mountains, to various stress factors of recurring droughts and rainfall variability notably the difficulty of producing enough food locally, possibly lead to food insecurity, and outbreak of waterborne diseases. Particularly, in the mountains, people rely on natural resources which are threatened by drought conditions, rendering their lives vulnerable and making poor people more sensitive to changes in the environment. The population density in the southern lowlands is high, therefore any climatic hazard affects many people, thus adding to the region’s sensitivity and vulnerability. The El Niño phenomena in particular affects climate variation in Lesotho where high intra-seasonal and inter-annual rainfall variability, with frequent droughts, has often resulted in delayed planting or farmers not planting at all, reduced seed germination due to hardened soil and lack of water, crop failures, deterioration of rangelands and pastures and water scarcity for livestock (Dejene et al., 2011).

The Southern Lowlands and the Mountains are negatively exposed to climate variability and are also highly sensitive, based on serious land degradation, high reliance on rain-fed agriculture (often in monoculture), low economic and agricultural diversity, compounded by the burden placed on economically active adults in caring for children, the aged and the sick, and a high rural population density (OWSI, 2009). Thus, the impacts of climate change are expected to be severe. However, at the household level, higher levels of agricultural and economic diversity in the "middle" and "better-off" wealth groups would reduce the impact somewhat (OWSI, 2009).

According to the latest model projections for Lesotho (LMS, 2018), there is an overall projected increase in daily minimum temperatures countrywide towards the turn of the century. Furthermore, the mountains hosting most of the SRV livelihood zone have had the lowest daily minimums compared to the lowlands. However, model projections show a gradual increase in daily minimum temperature across periods of projection for all the Representative Concentration Pathway scenarios. Thus, climate change will aggravate water stress, which is already palpable especially in the southern lowlands and lower Senqu River valley where people are already at risk of water stress from low annual average rainfall (400–500 mm).

While climate-related stresses have been prevalent in Lesotho for a long time especially for communities in the southern lowlands and Senqu River Valley, people evolved within this climatic context and have developed a range of coping mechanisms which have served them well in the past (Dejene et al., 2011). What has changed in recent times, however, is the apparent increasing frequency, magnitude and duration of climatic shocks, leaving little or no time to recover from the last event as evidenced by the drought episodes of the early 1990s (Fig. 1).

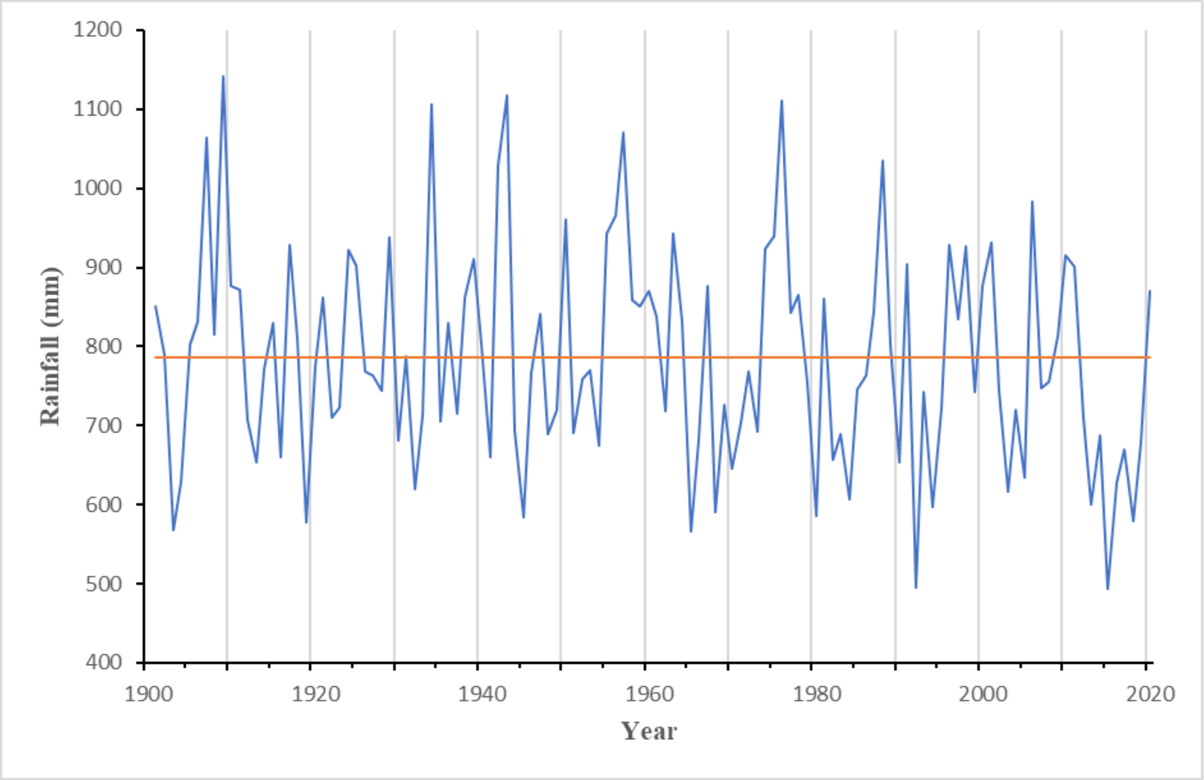

Figure 1. Lesotho Annual rainfall from the year 1901 to 2020. Long term average = 785 mm. Source: WBG open data source accessed (29-09-2021)

In addition, Lesotho has a heightened competition for arable land due to population increase and migration to the lowlands, competition for land between crops and livestock, lack of resting of the land and progressive loss of vegetative cover, rapidly dwindling soil and water resources, few opportunities for off-farm income, and deepening poverty which paints a gloomy picture of increasing inability to deal with additional climatic shocks (OWSI, 2009).

Several factors have also been mapped that contribute to the vulnerability of communities with respect to climate change impacts on food security and nutrition (WFP 2022). These have been drawn from existing studies including national surveys, a livestock vulnerability assessment conducted for the Wool and Mohair Promotion Project (WAMPP), and WFP. Each of these factors have been modelled spatially to provide an indication of the distribution of these factors across the southern lowlands and foothills.

a) Poverty

Poverty is a critical driver of vulnerability since it directly influences the level to which a household or community can respond to climate change impacts and the extent to which they can employ adaptive measures in response to climate change. Poverty data from the Lesotho Bureau of Statistics was used to map the distribution of poverty at a Community Council scale

(WFP 2022). This data shows that poverty is most intense in the north-eastern areas corresponding to the highlands of Mohale’s Hoek and Mafeteng Districts. Poverty is also seen to be lowest in Community Councils containing major centres and good access routes in the form of main roads. These features are largely absent in the areas with the highest incidence of poverty especially the greater Senqu River Basin (SRB).

b) Distance from urban centres and trade markets

There is mounting evidence that the distance from urban centres plays an important role in the development of communities and in determining their vulnerability to climate change impacts. This is especially true in Lesotho where the rugged terrain and the limited number of roads makes transporting any produce to market or being able to purchase food or building materials difficult. To understand the distribution of this contributing factor, a spatial analysis was carried out that assessed the effective distance of all areas to urban centres (WFP 2023). This effective distance incorporated an accessibility cost based on slope, which accounts for the inaccessibility of steep mountainous areas. The flatter areas of the southern lowlands are shown to be reasonably accessible, whilst the mountainous areas of the greater SRB seen to be effectively much further from centres of trade and consequently vulnerable to climate change impacts.

c) Livestock vulnerability

Many households in Lesotho especially in the mountains of which SRB is a greater part, are reliant on livestock for their livelihoods. A study into identifying the extent and distribution of livestock vulnerability to climate change related hazards was conducted as part of the WAMPP project. For that study, livestock vulnerability was assessed based on the distribution of criteria such as rangeland health, access to rangeland, animal husbandry and various others. Vulnerability indicator data for the WFP study area (WFP 2023) have been extracted from the outputs of the WAMPP study. These suggest that vulnerability is greatest in the relatively densely populated and highly transformed landscape of southern lowlands where grazing availability is lowest.

d) Access to arable land

Arable land is a critical resource in Lesotho where a high proportion of the population depends largely on growing their own food. Lesotho’s topography also means that this is a limited resource, particularly in the foothills, highlands and Senqu River Valley. Given the limited area available for cultivation, the availability of such land has been assessed based on the current area under cultivation. This assumes that any land that is reasonably arable has already been cultivated. Only very marginal and completely non-arable land (steep slopes and shallow soils) remains. Lesotho's national land cover data was used to identify cultivated areas. This assumes that the land available to a village community is that which is closest to that village and not closer to another village. This analysis indicates that the areas with poorest access to arable land are those villages in the south-eastern lowlands and foothills corresponding to the more mountainous areas.

1.4. Sector selection

1.4.1. Expected climate change and its impacts in vulnerable sectors

Climate models in the Lesotho Third National Communication to the Conference (TNC) of the Parties (LMS, 2018), project more frequent droughts and dry spells with erratic precipitation and high intensity torrential downpours with prolonged wet periods in the mid-term (2045-2070), and possibility of amplified drought in the long term (2071 – 2100). In the southern lowlands and Senqu River Valley livelihood zones, projections show compounded likelihood of intensified incidence of drought spells and incidence of heavy to extreme precipitation with potential flooding consequences. All these phenomena will increase the risk of soil erosion and vegetation damage through runoff. Overall, the models project decreasing precipitation falling erratically with high intensity storms. Thus, climate change will aggravate water stress, which is already palpable especially in the southern lowlands and lower Senqu River valley where people are already at risk of water stress from low annual average rainfall (400–500 mm).

a) Temperature

According to the latest model projections for Lesotho (LMS, 2018), there is an overall projected increase in daily minimum temperatures countrywide towards the turn of the century. Furthermore, the mountains hosting most of the SRV livelihood zone have had the lowest daily minimums compared to the lowlands. However, model projections show a gradual increase in daily minimum temperature across periods of projection for all the Representative Concentration Pathway scenarios. Other studies (WFP 2022) identified indices indicative and reflective of key hazards for Lesotho especially southern districts.

i) Change in the monthly maximum value of daily maximum temperature.

Changes in the monthly maximum of daily maximum temperatures from the historical baseline are forecast to be broadly similar across southern Lesotho including lower SRV with an approximate increase of between 2.4 and 2.6^{o}C (WFP, 2022). A slightly larger increase is evident in the eastern highland areas, but essentially the change is similar across the study area. Increased maximum temperatures are likely to affect crops and livestock through increased heat related stress, though this is likely to affect the lower lying southwestern lowlands to a greater degree due to the higher baseline temperatures already experienced there.

ii) Change in annual total number of frost days (where minimum temperature < 0^{0}C)

The number of frost days (where the minimum temperature is below 0^{o}C) is forecast to reduce substantially across the southern lowlands and foothills, though with a much larger reduction being noted in the high lying central and eastern mountain areas (WFP, 2022). This is because the highlands presently experience a much higher incidence of frost days than the lowlands areas. This is likely to have two major impacts, namely 1) improved crop growing conditions where frost damage to crops is less frequent, though it is recognised that most of the frost presently occurs outside of the crop growing season, and 2) increased prevalence of parasites such as ticks and their associated diseases given that frost and below freezing temperatures is a major tick control factor. Livestock in the highlands particularly are thus at increased risk from such threats.

iii) Change in the length of the growing season (temperature only)

The length of the growing season (temperature only) is forecast to be increased everywhere in Lesotho, though significantly more in the high lying eastern areas (WFP, 2022). This is a further reflection of a general warming of Lesotho, of which the SRB constitutes at least 75 percent. This means temperatures suitable for crop growing occur over a much longer period than what was historically the case. Importantly though, if this extended growing season is not accompanied by sufficient precipitation, the change will not allow any improvement in cropping conditions. It does, however, mean that if the onset of rainfall is delayed, crops that are planted late are less likely to fail due to frost or other cold related issues. The change does, however, open the potential for expanding the range of crops.

b) Precipitation

i) Change in the total volume of annual precipitation

The volume of total annual precipitation is projected to undergo a change ranging from a reduction of close to 6% in the higher lying eastern and southern areas to an increase of nearly 4% in the western areas (WFP, 2022). Whilst this indicator is an important one, it should be considered that it does not indicate the timing nor the nature of the precipitation. Timing is a vitally important aspect for the cultivation of crops and there are unfortunately no data reflecting the timing of the onset of the rainy season for example. The forecast change in the volume of precipitation should also be considered in conjunction with the forecast change in the intensity of precipitation which suggests that the increase in volume is likely to be in the form of more intense events, and not an increase in the number of precipitation events.

ii) Change in the intensity of rainfall

Rainfall intensity is projected to increase over most of the country especially the southern lowlands with the greatest increase in the central high lying areas around Semonkong (WFP, 2022). The exception to this is the area in the extreme southern lowlands and lower SRV where a slight reduction in intensity is projected. Rainfall intensity is important since it influences the amount of water infiltrates the soil and how much runs off over the surface. This influences the erosive potential of a rainfall event and the potential of that event to cause flooding. From a soil erosion perspective, the Senqu River valley is shown to be increasingly vulnerable, whilst the lowland areas of the Mafeteng District show increased vulnerability to both soil erosion as well as flooding.

c) Water resources and water infrastructure

A slight decrease in the projection of rainfall in the southern lowlands and mountains could impact potable and non-potable water supply (WFP, 2022). In some parts of the country extreme rainfall events could result in water contamination and overflow of dams. Currently, flooding episodes in Lesotho are palpable. Thus, extreme rainfall events in the future could exacerbate the currently observed impacts on storm water drainage to a point where networks would be unable to cope with excess runoff, leading to flash flooding both in the urban and in the rural areas. Cyclones, droughts, storm surges and other extreme events could damage storm-water infrastructure and disrupt drainage through blockage or excessive water. Increases in high intensity cyclones could damage water supply infrastructure and disrupt water treatment and distribution, leading to shortages of clean, safe drinking water. The extreme events could also impact the functioning of wastewater treatment plants and would lead to overflowing of wastewater treatment ponds, resulting in contamination of water supply and waterways.

d) National development and infrastructure

Cursory analysis of the current situation and state of economic networks shows that the advent of climate change is putting Lesotho's infrastructure under pressure. Extreme events such as flooding cause economic losses estimated at proportions of 3.2% of GDP (DMA, 2011). This is particularly bad for poor people who live in inadequate housing that is more prone to damage in the rural and peri-urban environments. The current rate of soil erosion and land degradation and resultant reduction in arable land (Lesotho Land Degradation Neutrality, 2018), poverty and joblessness rise (LVAC 2018) explains the apparent migration to urban centres, causing overcrowding and urban sprawl of the metropolitan areas especially Maseru and Maputsoe. The resultant overcrowding is already putting immense pressure on services and utilities to cope with the demands resulting from demands for electricity service, water shortages and disease outbreaks. In several lowlands areas of Lesotho e.g., Tsikoane in Leribe, floods annually cause damage to houses, road infrastructure and and endanger the occupants.

e) Health sector

The projected climate change will increase the incidence and severity of vector-borne, zoonotic, and infectious diseases. Water-borne diseases and diseases transmitted through mosquitoes are also affected by climate change. Sensitivity to climatic conditions is not only limited to the duration of transmission but may also affect geographical distribution. The social and environmental determinants of health, such as access to clean and safe drinking water, sufficient food, secure shelter and hygiene and sanitation are also exposed to climate threats. Lesotho is susceptible to climate-sensitive diseases such as typhoid fever and diarrhoea, which become widespread after floods and cyclones. There could be psychological impacts as well due to population displacement and income loss leading to depression and mental illness.

1.4.2. Process and results of sector selection

An extensive review and analysis of policy and other documents pertaining to climate change and adaptation actions was carried out in conjunction with wider stakeholder engagement to identify sectors that are most vulnerable to climate change at the Inception Workshop held on 22nd January 2022. As the Focal Point of the UNFCCC, the Department of Meteorology responsible for mainstreaming climate change adaptation and mitigation into the economy, the

LMS and NCCC acted in their advisory capacity. They informed the sector prioritisation process based on the mitigation, adaptation and development priorities of the country. The prioritisation of sectors for the TNA project primarily depended on the outcomes of a number of studies and policy documents read together with the NAPA. The criteria chosen for sector selection are as follows:

- Increasing resilience of the sector will support the objectives of the NSDP II and will eventually lead to a climate resilient economy and sustainable development;
- The vulnerability of the sector to the projected climate change is extremely high and requires intervention such as climate financing and innovative technologies to reduce vulnerability.
- Size of the population affected by climate change hazards and enhancing or upscaling adaptation options in these sectors will safeguard the livelihoods of the Basotho people especially those in the rural areas.
  a) Vulnerability assessments strongly highlights that Lesotho's economy is more vulnerable to natural hazards such as floods, extreme weather events and to some extent drought and consequently, the following sectors, were broadly considered for prioritisation: Agriculture (Crop and livestock sub-sectors), Water Resources and Infrastructure.

The sector selection was based on the recommendations of the NCCP 2017-2027 taken together with the NDC 2020/2021 which identified and prioritized adaptation priorities to drive a climate proof economic agenda:

i) Agriculture

In Lesotho, a large proportion of the population ekes their livelihoods and income from the agricultural sector mainly in the crops and livestock sub-sectors. However, climate change already precipitated extreme weather and climate variability manifested by among others prolonged and intense drought, heavy rain, early and late frosts, agricultural production is highly erratic. Therefore, a climate resilient agricultural sector was deemed necessary to ensure long-term agricultural production. However, pursuant to the NAPA, the prerequisite was to climate proof the sector by addressing climate change imperatives and provide mechanisms to enhance climate change resilience (including water harvesting and storage for irrigation, introduction of improved drought resistant seed varieties and climate change adapted cropping patterns), developing and implementing 'climate screening guidelines' for the agriculture sector to identify and mitigate risks and exploit opportunities posed by climate change, practising conservation agriculture.

ii) Water resources

In a changing climate regime, availability and access to water are critical for meeting domestic water needs, livestock rearing, crops irrigation, hydropower generation and industrial activities. Climate change projections for Lesotho (LMS, 2018) indicate severe impacts on water resources due to diminishing rainfall into the distal periods leading to the shrinkage of surface and ground water resources. The issue of management and conservation of water resources is arguably one of the most critical developmental challenges in Lesotho. The proposed adaptation measures (Lesotho Water and Sanitation Policy 2007): promotion of integrated water resources management, a policy-based approach to integrate climate change adaptation into water policies, promotion of water recycling and procurement of requisite equipment, conservation of wetlands and mountain sponges, intensification of investment in purification technology.

iii) Infrastructure

Effective and reliable infrastructure is the mainstay of economic activity and a driver of economic growth. The impacts of the 2010/11 heavy rains showed the risks that infrastructure could face and the significant economic damages and losses that these types of events result in. With climate change, extreme weather events could become more frequent and extreme, so too will the level of destruction if adaptation measures are not taken into consideration. Building a climate resilient infrastructure can be achieved by; developing technical guidelines on the integration of climate change in the planning and design of infrastructure in climate-sensitive sectors and by developing new building standards that consider issues of climate change.

iv) Sustainable land management

The importance of sustainable land management in Lesotho derives from the fact that close to 85 percent of the population derive all or part of their livelihood from agriculture. However, the suitability of these soils is greatly influenced by topography, the highly variable rainfall pattern that includes both droughts and heavy rains, animal and human pressure, the cultivation of marginal lands, and poor land management practices, factors which have combined to expose the country to severe forms of soil erosion. Climate change is expected to exacerbate soil erosion due to the prolonged and frequent droughts and heavy rains that would leave the soil surface bare. Measures to curb soil erosion under climate change include; promotion of land management practices and land reclamation techniques, promotion of biological measures of erosion control.

- **Rangeland resources:** Rangelands serve as grazing land for pastoralists. Livestock rearing in the rural areas entirely relies on open land grazing as commercial fodder production is minimal. About 70 percent of Lesotho's land area, approximately 1 981 896 hectares, is rangelands. Increased temperatures and the change in precipitation pattern are likely to negatively affect the country's vegetation and rangelands. This would result in reduction in vegetation and forage productivity. Adaptation measures in the sector include; proper management of rangelands, promotion of the use of fire breaks and increasing public awareness on fire hazards and management.
- **Forest resources**: Basotho depend on both indigenous and exotic forest resources for fuel wood, to prevent soil erosion, for income generation, building material and for forage. Lesotho is one of the least forested countries in Africa with less than one (1) percent of the country being occupied by forest or woodland. Forest resources are vulnerable to extreme climatic conditions as they affect the resilience and regenerative capacity of forest resources. Forest resources are expected to be reduced by the changing climatic conditions. Adaptation measures include; investing in implementation of good forest management plans, selection of pest resistant or drought tolerant intensification of afforestation programmes, reforestation of multi-purpose trees, introduction of grafted trees and varieties. Forest cover will increase to 21,000 ha by 2020.

Health: Lesotho has in the past been free of climate related diseases due in part to high altitude and extremely cold winters. Climate change induced droughts can diminish dietary diversity and reduce overall food consumption and therefore lead to micronutrient deficiencies. There are also indications that the country is likely to have a warmer climate in the future. This could lead to incursion of tropical diseases into the country. Proposed adaptation measures include; surveillance and monitoring, knowledge management, popular participation, education, ecosystem interventions, medical interventions, institutional and policy interventions.

Based on the development priorities and criteria for sector selection, with compelling evidence from vulnerability assessments and related policy and strategy documents, the two priority sectors retained through the consultation process carried out by the Adaptation Consultants for the TNA process are: Agriculture and Water Resources.

Chapter 2 Institutional arrangement for the TNA and the stakeholder involvement

The Lesotho Meteorological Services in collaboration with the multi-stakeholder NCCC acts as the coordinating agency for the implementation of the NCCP 2017-2027. It is responsible for the coordination of climate finance and the implementation support and reporting associated with the NSDP II, NDC, and NAP. Furthermore, LMS is responsible for liaising with and reporting to the UNFCCC as well as ensuring transparency, integrity, and consistency of reporting. As the Coordinating Agency for NCCP, LMS supports climate-change knowledge management by developing communications strategies, developing, and maintaining data repositories, and supporting functions and knowledge products designed to raise awareness of key climate-change issues in government, the private sector, and civil society. LMS works to provide support to government ministries in national efforts to mainstream climate change into development planning, sectoral planning and strategies, decision making, and policy. As the UNFCCC National Designated Entity and Focal Point, LMS is also the National Contracting Entity for the TNA Project. Through the Technology Needs Assessment Project, LMS aims to uphold the principles of the NCCP to achieve a resilient and prosperous Lesotho, in which the well-being of current and future generations is supported and protected by a socially inclusive, equitable, environmentally sustainable, net-zero emissions economy. The TNA will allow Lesotho to assess technologies that are vital for a resilient and low carbon Lesotho. A TNA is a solution for developing countries such as Lesotho that struggle to secure climate finance to address their development needs.

Lesotho developed and adopted a Climate Change Policy in 2017. The Policy, inter alia, outlines the institutional roles and responsibilities of various role players at different levels of engagement (Table 1).

Table 1. Roles and responsibilities of various institutions in the implementation of climate change policy

Level	Structure	Roles and responsibilities
Policy	Parliament and Natural Resources, Tourism and Land Portfolio Committee	➢ Oversees the implementation of NCCP ➢ Review legislation to support implementation of the NCCP
	Cabinet	➢ Approves policies
	Ministerial Committee on Climate Change	➢ Coordinates and aligns climate change responses with national, sectoral policies and legislation
	Ministry of Energy and Meteorology	➢ Coordinates implementation of NCCP ➢ Ensures that the Lesotho adheres to and implements commitments under the UNFCCC and the Paris Agreement

National	National Climate Change Committee	➢ Serve as an advisory body on issues relating to climate change. ➢ Enhances coordination and dialogue among stakeholders on issues of climate change ➢ Promotes information sharing and raise awareness on issues of climate change
	Department of Meteorology and Climate Change	➢ Serves as the Secretariat of NCCC ➢ Ensures proper implementation of the NCCP and commitments under the UNFCCC ➢ Enhances transparency through reporting requirements set under the UNFCCC and Paris Agreement
	State and Non-State Actors	➢ Implement sector specific actions under the NCCP ➢ Provide climate change related data and information
	Technical Expert Groups	➢ Provides technical guidance on climate change issues
Local	Climate Change District /Local Committees	➢ Ensure that NCCP implementation is balanced and meets the needs of district and local communities

2.1 National TNA team

The country-driven nature of the TNA required an inclusive and participatory process that ensured that the prioritised technologies were a true reflection of the national needs. The Department of Science and Technology is the designated national institution, and it leads and coordinates the TNA process in Lesotho. The LMS is the Focal Point for the United Nations Framework Convention on Climate Change (UNFCCC). The key elements of the institutional setup of the national TNA process include the Cabinet, the NCCC acting as a TNA Project Steering Committee, the TNA Coordinator, the National Consultants, and the Sectoral Working Groups. Fig. 2 maps the institutional arrangements for coordination of climate change issues and contextualizes the national institutional setup for the TNA project in Lesotho.

The Department of Meteorology or Lesotho Meteorological Services (LMS) is charged with the responsibility of monitoring and reporting on weather, climate and climate change issues. In addition, it ensures that the country adheres and implements commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. To streamline this mandate, A National Climate Change Committee (NCCC) was formally established in 2013 to effectively coordinate climate change issues in the country.

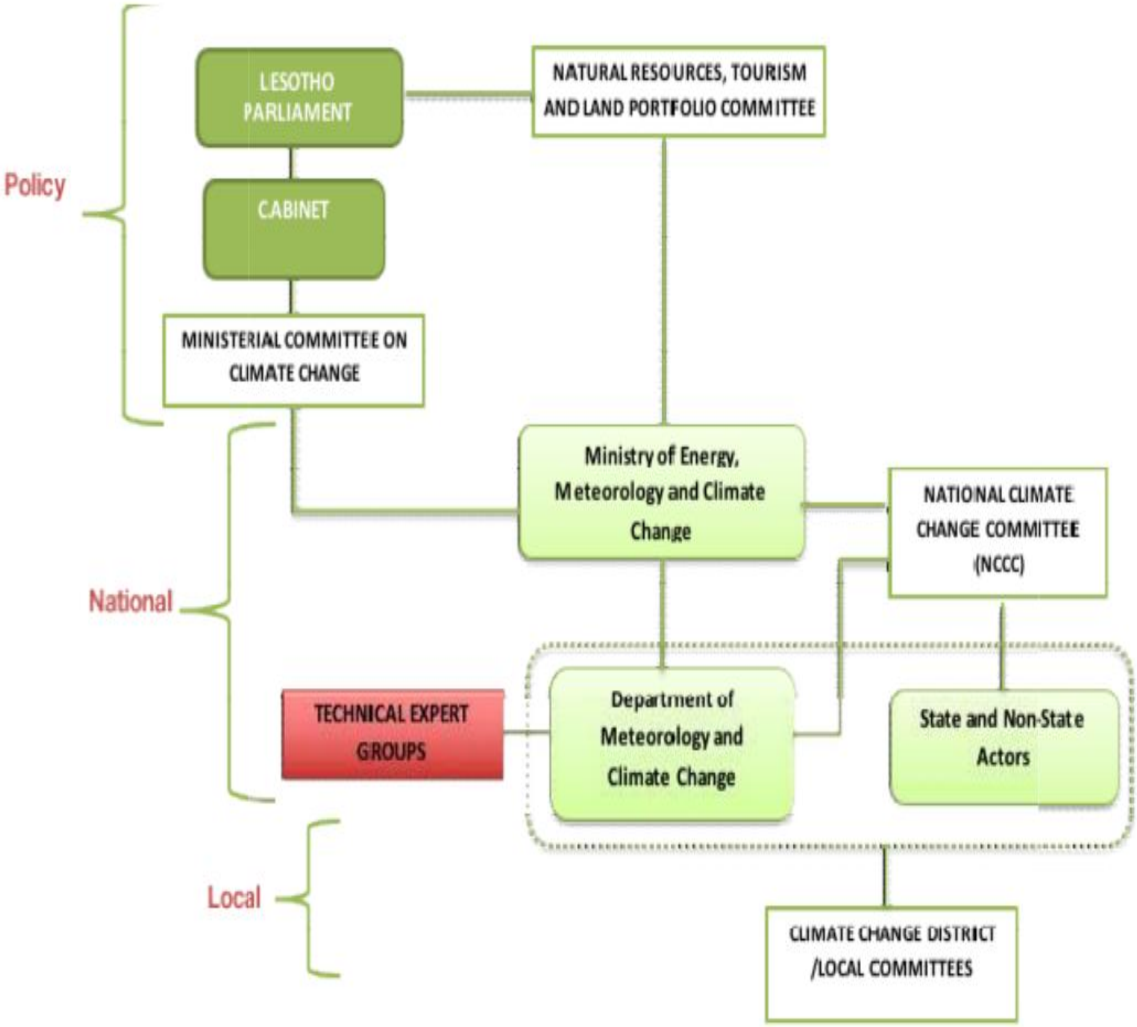

Figure 2. Institutional arrangements for coordination of climate change issues in Lesotho.
Source: Lesotho Climate Change Policy.

The committee serves as an advisory body to the Ministry of Energy, Meteorology and Climate Change (MEM)[1]. In the context of the TNA project, four key institutional nodes of the project i.e. NCCC, the National TNA Coordinator, the Sectoral Working Groups and Consulting Team (Fig. 3). The role of the National TNA Coordinator is to act as a focal point for the Department of Meteorology guiding the development and progress of the TNA within the country.

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[1] Now Department of Meteorology

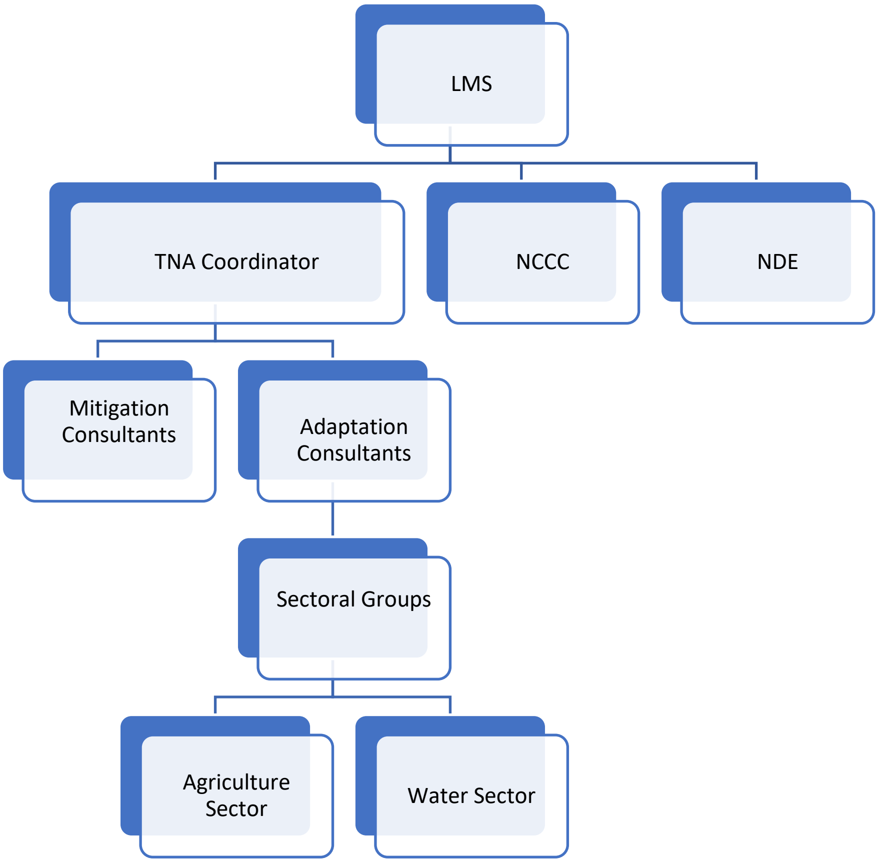

Figure 3. Project institutional setup.

TNA in Lesotho was performed with the involvement of local mitigation and adaptation experts. The lead national consultants were selected by the National TNA coordinator in close consultation with UNEP following an open and transparent selection process. The Mitigation Consultant is Prof Taele Molibeli, a professor of Physics at the National University of Lesotho. He is assisted by Dr Mphethe Tongwane. Prof Molibeli has contributed to many studies pertaining to renewable energy and energy modelling and forecasting in Lesotho. The Adaptation Consultant is Prof Makoala V. Marake, a professor of Soil and Water in the Faculty of Agriculture at the National University of Lesotho. Prof Marake has broad experience in agriculture, climate change science and natural resources adaptation. He is assisted by Ms Joalane Marunye, a Lecturer in the Department of Geography and Environmental Science in the Faculty of Science and Technology at the National University of Lesotho. National expert consultants are responsible for finalising the TNA Report after thoroughly identifying and prioritising technologies for the two sectors identified under climate change adaptation and mitigation after exhaustive consultation with the relevant stakeholders and experts. The National Consultants lead the process of the Multiple Criteria Analysis (MCA), along with the national stakeholder groups, and facilitate the process of technology prioritisation addressing the barriers and developing an enabling framework.

The successful implementation of National Climate Change Policy is much dependent on active support and effective participation of all stakeholders. Proper coordination and mainstreaming of climate change activities into different sectors of the economy is key to addressing the issues of working in silos by various departments, institutions, and organizations; a state that could lead to disharmony between different actors and undermine its effectiveness and efficiency. It is against this background that the National Climate Change Policy proposed the establishment of an institutional framework and set up that will be effective in implementing the Policy (Fig. 2 and Table 1).

2.2 Stakeholder engagement process

The stakeholder consultation process for the TNA work followed the principles of sustainable wellbeing, inclusivity, social cohesion, partnership, agility, urgency, transparency, and communication and integrated learning as deliberated by NCCP 2017-2027. Stakeholders include government ministries /departments, private sector, non-government organisations, civil society organisations and academia. The TNA Report was prepared after an extensive stakeholder process[2]. The key and successful stakeholder engagement methods included:

- Email correspondence and exchanges on the Technology Factsheets (TFS), which allowed the stakeholders to become well versed in the technologies and provide meaningful feedbacks during the stakeholder consultation workshops.
- Bilateral engagement, which proved a very useful way to engage experts in a particular field, especially when the stakeholder was not able to attend the workshops.
- Awareness workshop for selected sectors that facilitated formation of technical working group; and
- National stakeholder consultation of key stakeholders for technology prioritisation.

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[2] Stakeholders were first consulted through an Inception Workshop (21st January 2022) attended by key Ministries and Departments as well as Non-Governmental Organizations and the private sector. The purpose of the Inception Workshop was first to introduce the Consulting Teams and secondly, the TNA process to critical stakeholders and thirdly to sound the participants on the indicative priority sectors. In a subsequent engagement, a series of two workshops was conducted with the same 44 stakeholders (Annex III). First to interrogate the draft reports and validated the prioritization of the sectors (22nd March 2023). In the second sitting (29th March 2023), a technology assessment and prioritization session was help in which the Consultants lead the MCA process culminating in the final choice of technologies.

The national inception workshop held to launch the Technology Needs Assessment (TNA) Project in Lesotho provided a forum for deciding on which sectors to work on under adaptation. The workshop was aimed at facilitating enhanced awareness and active engagement of a broader group of stakeholders on the TNA process and addressing relevant issues relating to the TNA process such as the choice of the sectors for the TNA. The water, agriculture and infrastructure sectors were initially proposed as the sectors to be considered under adaptation. However, following discussions and through use of the MCA technique, the workshop participants decided on the agriculture and water resources sectors since both sectors are at the base of the country's socio-economic development. It was also suggested that infrastructure be an integral element of both the agriculture and water resources sectors.

2.3 Consideration of gender aspects in the TNA process

Lesotho developed a National Gender Policy in 2022 to promote gender equity, equality, social justice, and sustainable development. The NCCP 2017-2027 makes a bold statement on gender responsiveness. The Policy bridges the gap and provides gender sensitive guidelines and inclusive participation of youth and vulnerable groups. An inclusive society is one that overwrites differences of race, gender, class, generation, and geography, and ensures to determine an agreed set of social institutions that govern social interaction. The key principles of a gender inclusive policy are:

- Recognizing the need for climate change measures that ensure inclusive participation of youth, gender and vulnerable groups.
- Recognizing the need for capacity building for youth, gender and vulnerable groups and creating an enabling environment for participation at all levels of planning and decision making.

In Lesotho women play a unique role in natural-resource management but are uniquely vulnerable to climate change. However, they are also the agents of change in societies. Thus, improving and enhancing the incorporation of women's knowledge, skills, participation, and leadership into planning processes at the local and national level creates opportunities to maximise both women and men's contributions to environmental sustainability. The TNA work in Lesotho builds with the guidance of the NCCP and Sustainable Development Goal 5. Women civil society representatives have been included in the technical working groups and the stakeholder consultations. The technologies prioritised were evaluated for gender sensitivity, which was included as included as a criterion under the social benefits. In the instance of this TNA, equal opportunities have been provided to both men and women to voice their opinions and standpoints. The Lesotho TNA process was also inclusive of the disabled and Lesbian, Gay, Bisexual, Transgender and Queer (or questioning) and others (LGBTQ+) groups.

Chapter 3 Technology prioritisation for the agriculture sector

3.1 Key climate change vulnerabilities in the agriculture sector

Climate change poses significant challenges to various sectors. However, the agricultural sector is particularly vulnerable to the impacts of climate change with potential consequences for food security, livelihoods, and overall socio-economic development.

a) Water scarcity

Water scarcity is a major vulnerability to climate change in Lesotho's agriculture sector and will be exacerbated by the projected climate change (LMS, 2018). Furthermore, southern Africa is projected to be a hot spot of climate change impacts (Lobell et al., 2008) potentially experiencing reduced precipitation leading to intense and frequent drought (IPCC, 2014). The country heavily relies on rainfed crop production systems especially cereal staple crops of wheat, beans, sorghum and maize. Rainfall also provides critical source of water for irrigation of horticultural crops especially vegetables. However, changing weather patterns, including irregular rainfall, frequent and prolonged droughts, pose a significant threat to water availability. Reduced water availability hampers crop growth, livestock rearing, and overall agricultural productivity. Farmers are forced to rely on limited water sources, impacting their ability to maintain stability of production systems and sustain food and nutrition security for their livelihoods. In addition, projected drought conditions are likely to negatively impact on the stability and integrity of the Lesotho highlands water arrangements with South Africa precipitating a loss of income from royalties.

b) Decreased crop yields

Shifts in temperature and precipitation patterns can result in reduced crop yields or outright crop failure. Lesotho's agricultural sector heavily depends on rain-fed farming, making it highly susceptible to variations in rainfall. Rising temperatures and unpredictable rainfall disrupt planting and harvesting schedules, negatively impacting crop growth and quality. Additionally, extreme weather events, such as floods and storms, can destroy crops and infrastructure, exacerbating food insecurity and economic losses for farmers. For example, the 2010/11 floods caused the country in excess of 3.2 percent of the GDP (GOL, 2011). Increasing temperature and rainfall have an impact on the Soil Organic Carbon (SOC) and thereby affects soil fertility. A recent study revealed that climate change has some impact, but the major driver is land-use changes (Zhou et al., 2019).

c) Soil erosion and land degradation

Climate change-induced factors, such as increased temperature, erratic rainfall, and extreme weather events, contribute to soil erosion and land degradation in Lesotho. The country's predominantly mountainous terrain makes it susceptible to soil erosion, which further degrades agricultural land. Soil erosion reduces soil fertility, nutrient content, and water-holding capacity, making it difficult for farmers to cultivate crops successfully. This degradation affects long-term agricultural sustainability and the ability to adapt to changing climate conditions. The economic cost of land degradation costs the country an excess of US$57, 000 per annum (Land Degradation Neutrality, 2016).

d) Livestock vulnerability

Livestock contributes 75 percent of the total agricultural output and constitutes 52% of agriculture GDP, including semi-intensive and intensive production of pigs and poultry, as well as extensive (free range) production of goats and sheep on rangelands in the foothills and highland areas (CNAP 2022-2026). However, climate change impacts, including increased temperatures, water scarcity, and the spread of diseases, pose significant threats to livestock health and productivity. Heat stress reduces livestock productivity, and limited water availability impacts their overall well-being. Furthermore, changing climatic conditions facilitate the spread of vector-borne diseases, affecting animal health and increasing mortality rates.

e) Vulnerability of rural communities

The vulnerabilities in Lesotho's agricultural sector have far-reaching consequences for rural communities. Agriculture is the primary source of income and livelihood for over 80 percent of the rural households (NSDP II Strategic Focus: 23/24 – 27/28). Climate change-induced disruptions in crop production and livestock rearing directly affect the socio-economic well-being of these communities. Reduced agricultural productivity can lead to food shortages, malnutrition, and increased poverty levels (Makhetha-Kosi and Mashiloane, 2020). Moreover, the lack of alternative livelihood options further exacerbates the vulnerability of rural communities to climate change impacts.

The economic loss in agriculture is mostly incurred through natural hazards such as the flooding episodes of 2010/11, which will intensify in future, there are other climatic indicators such as heat stress or droughts that can impact the agriculture sector. The impacts of droughts include a decrease in agricultural production due to heat stress and lack of groundwater availability, the mortality of livestock, and the lack of drinking water. It is also anticipated that increases in daily temperatures and severe drought conditions could result in land degradation and desertification particularly in the rain shadow areas of Senqu River Valley and near arid southern lowlands.

The foregoing vulnerabilities have detrimental effects on food security, livelihoods, and overall socio-economic development. Addressing climate change impacts in the agricultural sector requires a combination of adaptation and mitigation strategies, such as implementing efficient water management techniques, promoting sustainable farming practices, and providing support to rural communities. Collaborative efforts by the government, international organizations, and local communities are crucial to building resilience, enhancing adaptive capacity, and ensuring the long-term sustainability of Lesotho's agricultural sector in the face of climate change

3.2 Decision context

The relevant policies and national development plans were discussed in section 1.2 and were used as a basis to prioritise sectors. The NAPA) is among the key documents that were used to identify technologies in the agricultural sector. The Lesotho NAPA process identified and prioritised the eleven adaptation activities for implementation in the various vulnerability zones to address the adaptation needs of communities within and seek to build capacity within designated vulnerable communities with a hierarchy of importance prioritizing agriculture (livestock and crop production i.e. Option 1 and 2 respectively) and securing Village Water Supply for Communities especially in the southern Lowlands (Option 5). In the backdrop of the NAPA, the NCCP 2017–2027 was developed to enjoin every sector and every role player to participate in the fight against climate change. The NCCP has an associated five-year strategic plan to implement it.

The NCCP 2017-2027 focuses on streamlining climate change issues in different sectors. Policy Statement 3 of NCCP 2017-207 calls for Climate-smart Agriculture as a tool to build national adaptive capacity in the agriculture sector in response to climate change hazards. Consequently, we used the Climate Smart Agriculture Investment Plan (CSAIP 2018) as a source document to inform prioritization because it aims to identify climate-smart agriculture (CSA) investments that offer the greatest potential to transform Lesotho’s agriculture into a more productive, resilient, and low-emissions sector because it is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change. In the context of Lesotho, CSA comprises three pillars: increasing productivity, enhancing resilience and adaptation, and reducing greenhouse gas emissions from the agriculture sector compared to the legacy. This report provides evidence showing that the adoption of CSA offers multiple wins: increased productivity and incomes; enhanced food security and dietary diversity; reduced impacts of climate change on agricultural produce; and improved commercialization, employment opportunities, and rural livelihoods. The report shows that CSA can also reduce soil erosion, generate carbon sequestration, conserve biodiversity, and provide other public goods that accrue to society—well beyond the farmers engaged in market transactions alone. The foregoing dovetails with the NSDP II (2018/19-2022/23) which regards the agricultural sector as a transformational thrust and engine for Lesotho’s economy, hence making the agriculture sector more resilient to impacts of climate change is a high national priority.

3.3 Overview of existing adaptation technologies in agriculture sector

The issue of food security and increasing agricultural productivity is enshrined in different national policies and plans. Consequently, some efforts in developing CSA technologies have been researched and piloted and /or promoted in the country. There have been "no-regret" measures (actions that would be worthwhile to implement even in the absence of climate change) such as climate resilient crop varieties (both hybrids and open pollinated) and animal breeds (both in small and large stock), which are a key adaptation strategy in the agriculture sector and have immense stakeholder and political acceptability in terms of both research and investment. In addition to modern technology, there is a strong commitment to technological interventions incorporating traditional knowledge, particularly in sustainable soil management such as the Machobane Farming Systems. There has been a significant amount of training and capacity building to promote sustainable soil management e.g. use of animal manure, irrigation technologies e.g. gravity-fed irrigation systems and drip, integrated pest management, and agroforestry e.g. interplanted orchard that will build the resilience of the local farming community and reduce vulnerability to the projected impacts of climate change.

Some of the existing technologies in the agriculture sector are:

- Improved crop varieties such as new hybrid varieties adapted from South Africa or developed locally e.g Sorghum Varieties (Thaha-Khube and NUL 2000) which are drought tolerant, fast maturing and bird tolerant.
- Drip irrigation and gravity-fed sprinkler irrigation demonstrations and to decrease the vulnerability of field and horticultural crops to water stress during the early plant development stages.
- Livestock disease surveillance in the country to boost the small stock (sheep and goats) and large stock (cattle and equines) industry.
- Animal breeding either using leveraging importation of improved breeds in small stock for wool and mohair, beef cattle, dairy cows (Friesian, Brown Swiss and Jersey cows) or artificial insemination to produce livestock breeds of favourable character, productivity and tolerance of local climatic conditions (extreme cold and heat stressors) and improve the genetics in animals for better meat and milk production.

- Promotion of exotic broiler /layer chickens and indigenous free-range chickens with Koekkoek layers
- Various Extension Models including limited trials and/or demonstrations of Farmers Field School (FFS) to provide non-formal education to young farmers to become self-employed in the agriculture sector. The Ministry of Agriculture and Food Security and various NGOs established demonstration farms and provided training to farmers including youth and women to incorporate inter-cropping farm systems to increase livelihoods. These players provided technical information on managing soil health using vetiver cultivation together with cash crops to avoid soil erosion by using locally available organic residues to increase soil organic matter.
- Pest and disease control using the Integrated Pest Management (IPM). IPM method were piloted in conjunction with biocides deemed harmless to introduce or natural enemies of these pests. To avoid the use of harmful pesticides such as organophosphates, more plant-derived products such as chilli combination to soap water were demonstrated.
- Promoting high intensity intercropping systems with organic manures to re-establish soil health or fertility.
- Composting of organic manures to produce compost from waste organic matter such yard and green market refuse.
- Agro-forestry demonstration plots and nurseries and various workshop promoting agro-forestry around the country to identify multipurpose agro-forestry crops with market potential and to enable enhanced and gender-equitable small-holder participation in agro-forestry crop production.
- Piloting and promotion of conservation agriculture to reduce soil erosion and increase productivity.

3.4 Adaptation technology options and benefits for agriculture sector

A range of technology options for the agriculture sector endorsed by stakeholders for their potential to reduce the sector’s vulnerability to the impacts of climate change are detailed below. The technology factsheets (Annex 1) contain detailed descriptions of the technologies, application potential in the country, cost implications, technical aspects, economic and environmental benefits.

3.4.1 Integrated climate change monitoring and early warning system

A climate change monitoring system for agriculture can provide several adaptation benefits in the face of climate change.

a) Early warning and risk assessment

A monitoring system can collect and analyze climate data to identify early warning signs of climate change impacts on agriculture. It can help assess the risks associated with changing temperature patterns, precipitation levels, and extreme weather events. By understanding the potential risks, farmers can take proactive measures to adapt their agricultural practices accordingly.

b) Improved decision-making

Accurate and up-to-date climate data provided by a monitoring system can support informed decision-making by farmers, policymakers, and agricultural stakeholders. This information can guide decisions related to crop selection, planting and harvesting schedules, irrigation management, pest and disease control, and resource allocation. By making data-driven decisions, farmers can optimize their agricultural practices to better cope with changing climate conditions.

c) Crop and livestock management

Climate change monitoring systems can help farmers track changes in climate variables such as temperature, rainfall, humidity, and solar radiation. This information can assist in determining the most suitable crops and livestock breeds for specific regions and seasons. It can also guide the implementation of adaptive practices such as altering planting dates, adjusting fertilization and irrigation techniques, and implementing heat stress management strategies for livestock.

d) Water management

Climate change often leads to changes in precipitation patterns, including increased variability and more frequent droughts or floods. A monitoring system can aid in monitoring water resources, including rainfall patterns, soil moisture levels, and water availability in rivers and reservoirs. By understanding these changes, farmers can make informed decisions about water allocation, irrigation techniques, and water conservation measures to optimize water use efficiency and adapt to changing water availability.

e) Pest and disease management

Climate change can affect the distribution and behavior of pests and diseases that impact agricultural crops and livestock. A monitoring system can help track changes in pest populations, disease vectors, and suitable habitats for pests and diseases. This information can support the development of early warning systems, pest and disease forecasting models, and targeted interventions to prevent and manage outbreaks effectively.

f) Infrastructure and resource planning

Climate change monitoring systems can provide valuable information for infrastructure planning and resource management in agriculture. By understanding climate change impacts on soil quality, land degradation, and water availability, policymakers and farmers can plan for necessary infrastructure developments, such as irrigation systems, drainage systems, and soil conservation measures. It can also guide resource allocation, including financial resources, human capital, and technology investments, to enhance agricultural resilience in the face of climate change.

Overall, a climate change monitoring system for agriculture can enable better adaptation strategies and practices by providing timely and accurate information on climate change impacts. By leveraging this knowledge, farmers and policymakers can make informed decisions to minimize risks, optimize resource use, and enhance the resilience and sustainability of agricultural systems.

3.4.2 Irrigation ranagement: drip system

Drip irrigation offers several benefits for climate change adaptation in agriculture.

a) Water conservation

Drip irrigation is a highly efficient irrigation method that delivers water directly to the roots of plants in small, controlled amounts. Compared to traditional irrigation methods like overhead sprinklers or flood irrigation, drip irrigation reduces water loss through evaporation and runoff. This water conservation is particularly crucial in the context of climate change, where water scarcity and variability are becoming more prevalent. Drip irrigation helps farmers optimize water use, cope with changing precipitation patterns, and adapt to periods of drought.

b) Precision watering

With drip irrigation, water is applied precisely to the plant root zone, ensuring that plants receive the right amount of water they need for optimal growth. This precision watering minimizes water wastage and allows for better control over soil moisture levels. Farmers can adjust the irrigation schedule and duration based on crop requirements and real-time climate conditions, thereby adapting to changing water availability and climate variability.

c) Reduced soil erosion and runoff

Drip irrigation delivers water slowly and directly to the soil, minimizing surface runoff and soil erosion. By reducing erosion, farmers can better retail valuable topsoil, prevent nutrient loss, and maintain soil fertility. This is especially important in areas prone to heavy rainfall or flash floods, where traditional irrigation methods can exacerbate soil erosion. Drip irrigation helps farmers adapt to changing rainfall patterns and mitigate the negative impacts of soil erosion on crop productivity.

d) Improved crop health and productivity

Drip irrigation provides a consistent and controlled water supply to plants, which promotes better crop health and productivity. By avoiding overwatering or underwatering, plants are less susceptible to water stress, diseases, and pests. Drip irrigation can also reduce the occurrence of foliar diseases, as it keeps the foliage dry. Improved crop health and productivity contribute to agricultural resilience, enabling farmers to adapt to climate change by maintaining stable yields and reducing crop losses.

e) Flexibility in irrigation scheduling

Drip irrigation allows for flexible irrigation scheduling, which is advantageous in the face of climate change. Farmers can adjust the frequency and timing of irrigation based on climate conditions, such as temperature, humidity, and rainfall forecasts. This flexibility helps optimize water use efficiency, adapt to changing climatic conditions, and reduce the risk of water stress on crops. Farmers can also stagger irrigation schedules to accommodate water scarcity periods or prioritize irrigation for more vulnerable crops or growth stages.

f) Enhanced nutrient management

Drip irrigation can be combined with fertigation, a technique that delivers fertilizers along with the irrigation water directly to the plant roots. This precision application of nutrients improves nutrient uptake efficiency and reduces fertilizer losses, resulting in better crop nutrition and reduced environmental impacts. By optimizing nutrient management through drip irrigation, farmers can adapt to climate change by ensuring the long-term sustainability of agricultural practices.

g) Energy efficiency

Drip irrigation systems are generally more energy-efficient compared to other irrigation methods. They require lower pressure and flow rates, reducing energy consumption for pumping water. As energy production often contributes to greenhouse gas emissions, adopting energy-efficient practices like drip irrigation helps mitigate climate change impacts and supports sustainable agricultural production.

Overall, drip irrigation offers significant benefits for climate change adaptation in agriculture. It conserves water, reduces soil erosion, enhances crop health and productivity, provides flexibility in irrigation scheduling, improves nutrient management, and promotes energy efficiency. By adopting drip irrigation, farmers can adapt their agricultural practices to cope with climate change, optimize resource use, and build resilient and sustainable farming systems.

3.4.3 Slow-forming terraces

Slow-forming terraces, also known as contour or bench terraces, are agricultural practices that involve creating levelled areas along the contours of sloping land to slow down the flow of water. These terraces offer several benefits for climate change adaptation in agriculture.

a) Soil erosion control

One of the primary benefits of slow-forming terraces is their ability to control soil erosion. By constructing terraces along the contour lines of sloping fields, they effectively intercept and slow down the flow of water, reducing the risk of soil erosion. This is particularly important in areas experiencing intense rainfall or heavy runoff, as it prevents the loss of topsoil, which is vital for maintaining soil fertility and crop productivity. Slow-forming terraces help farmers adapt to changing precipitation patterns and minimize the negative impacts of soil erosion on agricultural land.

b) Water conservation

Slow-forming terraces promote water conservation by facilitating water infiltration and reducing surface runoff. The terraces act as barriers, allowing water to spread across the slope and infiltrate into the soil rather than quickly running off the field. This promotes better soil moisture retention, particularly during periods of low rainfall or drought. The conserved water can be beneficial for crop growth, supporting adaptation to water scarcity and climate variability.

c) Improved soil moisture management

By slowing down the movement of water across the field, slow-forming terraces help in better soil moisture management. The terraces capture and retain water, allowing it to percolate into the soil profile and providing a more even distribution of moisture. This helps maintain optimal soil moisture levels for plant growth, reduces water stress on crops, and enhances agricultural productivity. Improved soil moisture management is especially valuable in regions prone to erratic rainfall or prolonged dry spells associated with climate change.

d) Enhanced nutrient retention

Slow-forming terraces can also contribute to improved nutrient retention in agricultural fields. By reducing surface runoff, the terraces help retain nutrients, preventing their loss through erosion and runoff. This is particularly relevant for water-soluble nutrients, such as nitrogen and potassium, which are essential for crop growth. By retaining nutrients within the root zone, slow-forming terraces promote efficient nutrient uptake by plants, leading to better crop nutrition and adaptation to changing climate conditions.

e) Increased crop yield and resilience

The combination of soil erosion control, improved water conservation, and enhanced soil moisture and nutrient management provided by slow-forming terraces ultimately leads to increased crop yield and resilience. The terraces create a favorable growing environment for crops by mitigating the negative impacts of climate variability. They help reduce yield losses due to soil erosion, water stress, or nutrient depletion, thereby improving the overall productivity and adaptive capacity of agricultural systems.

f) Long-Term soil health

Slow-forming terraces contribute to the long-term health and sustainability of agricultural soils. By preventing soil erosion, the terraces help maintain soil structure, organic matter content, and nutrient availability. This supports the soil's ability to retain water, resist degradation, and sustain agricultural productivity over time. Healthy soils are essential for climate change adaptation in agriculture, as they provide a solid foundation for resilient and productive crop growth.

g) Compatibility with agroforestry and biodiversity conservation

Slow-forming terraces can be integrated with agroforestry systems, allowing for the cultivation of trees or shrubs on the terrace edges. Agroforestry practices provide additional benefits, such as improved microclimate, soil stabilization, increased biodiversity, and additional income streams for farmers. The combination of slow-forming terraces and agroforestry contributes to climate change adaptation by enhancing ecological resilience, promoting carbon sequestration, and diversifying agricultural production.

Overall, slow-forming terraces offer significant benefits for climate change adaptation in agriculture. They control soil erosion, promote water conservation and soil moisture management, improve nutrient retention, increase crop yield and resilience, while improving crop productivity and resilience of farming systems. By adopting such practices, farmers can better cope with the challenges posed by a changing climate and ensure sustainable agricultural production.

3.4.4 Conservation Agriculture

Soil conservation agriculture, also known as conservation agriculture or sustainable agriculture, offers several benefits for climate change adaptation in agriculture.

a) Soil health and fertility

Soil conservation agriculture focuses on practices that prioritize soil health and fertility. By minimizing soil disturbance, such as reduced or no-till practices, and maintaining permanent soil cover through crop residues or cover crops, it helps preserve soil structure, organic matter content, and nutrient cycling. Healthy soils are more resilient to climate change impacts, such as extreme weather events, drought, or heavy rainfall. They provide a conducive environment for root development, nutrient uptake, and overall crop productivity, enabling farmers to adapt to changing climate conditions.

b) Water conservation and efficiency

Soil conservation agriculture practices contribute to water conservation and efficiency. The use of mulch or cover crops helps retain soil moisture, reducing evaporation and improving water infiltration into the soil. This can be particularly beneficial during periods of water scarcity or drought. By enhancing water availability and reducing water stress on crops, soil conservation agriculture supports adaptation to changing precipitation patterns and water availability associated with climate change.

c) Erosion control and soil stability

Soil conservation agriculture effectively controls soil erosion, which is a critical challenge in many agricultural landscapes. Practices like contour ploughing, terracing, or conservation tillage reduce the risk of soil erosion by minimizing the exposure of bare soil to rainfall or runoff. By preventing soil erosion, soil conservation agriculture helps maintain soil structure, prevents nutrient loss, and preserves valuable topsoil. This contributes to long-term soil stability, sustainable land management, and adaptation to climate-related events such as heavy rainfall or wind erosion.

d) Carbon sequestration and climate mitigation

Soil conservation agriculture has the potential to sequester carbon in the soil, thereby mitigating climate change. Practices that enhance soil organic matter, such as the use of cover crops or crop residues, promote carbon sequestration. Carbon sequestration in agricultural soils helps offset greenhouse gas emissions by removing carbon dioxide from the atmosphere and storing it in the soil as stable organic matter. By contributing to climate change mitigation, soil conservation agriculture supports global efforts to reduce greenhouse gas emissions.

e) Biodiversity and ecosystems ervices

Soil conservation agriculture promotes biodiversity and supports ecosystem services within agricultural landscapes. By reducing soil disturbance and providing permanent soil cover, it creates a favorable habitat for beneficial organisms like earthworms, microorganisms, and beneficial insects. These organisms contribute to nutrient cycling, pest control, and overall ecosystem health. The presence of diverse plant species, such as cover crops or agroforestry systems, further enhances biodiversity and provides additional ecosystem services. These services contribute to agricultural resilience and adaptation to climate change.

f) Resilient crop production

Soil conservation agriculture practices improve the resilience of crop production systems. By maintaining soil health, conserving water, and reducing soil erosion, they help crops better withstand climate-related stresses, such as heatwaves, drought, or heavy rainfall events. Resilient crop production systems are better equipped to adapt to changing climate conditions, ensuring more stable yields and reducing the risk of crop failures or significant losses.

g) Economic viability and farm sustainability

Soil conservation agriculture practices can contribute to the economic viability and long-term sustainability of farming operations. By improving soil health and fertility, reducing input requirements, and increasing water-use efficiency, they can lead to cost savings for farmers. Additionally, improved crop productivity, reduced soil erosion, and enhanced environmental stewardship can open up market opportunities and improve the overall economic sustainability of farming practices.

Overall, soil conservation agriculture offers multiple benefits for climate change adaptation in agriculture. It enhances soil health, conserves water, controls erosion, mitigates climate change through carbon sequestration, supports biodiversity and ecosystem services, promotes resilient crop production, and contributes to economic viability and farm sustainability.

3.4.5 Integrated soil nutrient management

Integrated soil nutrient management (ISNM) refers to holistic approach that combines various practices to enhance soil fertility and nutrient availability in agricultural system. It entails soil testing facilities with innovations such as mobile soil test laboratories. It provides several benefits for climate change adaptation in agriculture.

a) Enhanced nutrient availability

ISNM involves the use of various nutrient sources and management practices to optimize nutrient availability to plants. By incorporating organic amendments, such as compost or manure, and utilizing mineral fertilizers judiciously, ISNM ensures a balanced supply of essential nutrients to crops. This improves nutrient uptake efficiency and reduces nutrient limitations, especially in soils that may be depleted or deficient in certain nutrients. Adequate nutrient availability supports crop growth and productivity, allowing farmers to adapt to changing climate conditions and maintain stable yields.

b) Improved soil fertility

ISNM practices contribute to improving soil fertility. By incorporating organic amendments, such as crop residues or cover crops, into the soil, ISNM enhances organic matter content and nutrient cycling. Organic matter improves soil structure, water-holding capacity, and nutrient retention, promoting a favorable environment for plant roots and soil microorganisms. The improved soil fertility resulting from ISNM practices supports healthy plant growth, nutrient availability, and overall agricultural resilience in the face of climate change.

c) Increased soil carbon sequestration

ISNM practices can promote soil carbon sequestration, which plays a vital role in mitigating climate change. Organic amendments, such as crop residues or manure, contribute to the buildup of soil organic carbon. Increased soil organic carbon content not only improves soil fertility but also sequesters atmospheric carbon dioxide, reducing greenhouse gas emissions. Carbon sequestration in agricultural soils helps offset the carbon footprint of farming activities and contributes to climate change adaptation and mitigation.

d) Water use efficiency

ISNM practices can improve water use efficiency in agricultural systems. Proper nutrient management ensures that crops receive the necessary nutrients in the right quantities and at the right time. This promotes balanced crop growth and development, enabling plants to optimize water use. When crops have sufficient nutrients, they are better equipped to cope with water stress and use water more efficiently. Improved water use efficiency supports adaptation to changing precipitation patterns, water scarcity, and drought conditions associated with climate change.

e) Reduced environmental impacts

ISNM practices help minimize environmental impacts associated with nutrient management in agriculture. By optimizing nutrient use and reducing excessive fertilizer application, ISNM reduces the risk of nutrient runoff and leaching, which can contribute to water pollution and eutrophication of water bodies. Additionally, by promoting organic amendments and minimizing chemical inputs, ISNM reduces the release of greenhouse gases from fertilizer production and use. This leads to a more environmentally sustainable agricultural system and supports climate change adaptation and mitigation efforts.

f) Crop resilience and stress tolerance

ISNM practices can enhance crop resilience and stress tolerance. Balanced nutrient management ensures that crops have access to essential nutrients required for their growth and development. This supports robust root systems, efficient nutrient uptake, and improved stress tolerance, enabling crops to better withstand climate-related stresses such as heatwaves, drought, or extreme rainfall events. Resilient crops are more likely to adapt to changing climate conditions, maintain productivity, and reduce the risk of yield losses.

g) Sustainable agricultural production

ISNM sustains and contributes to the long-term sustainability of agricultural production. By optimizing nutrient use, reducing input costs, improving soil fertility, and minimizing environmental impacts, ISNM promotes sustainable farming systems. Sustainable agriculture is characterized by the efficient use of resources, environmental stewardship, and social and economic viability. ISNM practices support the sustainable intensification of agricultural production, ensuring the long-term adaptation and resilience of farming systems in the face of climate change.

Overall, integrated soil nutrient management plays a crucial role in climate change adaptation in agriculture by improving soil health, enhancing nutrient efficiency, promoting carbon sequestration, improving water management, supporting sustainable crop productivity, and conserving biodiversity. By adopting these practices, farmers can build more resilient and sustainable agricultural systems capable of withstanding and adapting to the challenges posed by climate change.

3.4.6 Crop diversity

Crop diversity refers to the practice of cultivating and maintaining a variety of different crops within an agricultural system. Crop diversity provides several benefits for climate change adaptation in agriculture.

a) Enhanced resilience

Crop diversity increases the resilience of agricultural systems to climate change impacts. Different crop varieties possess varying tolerances to different climate conditions, such as drought, heat, or pests. By cultivating a diverse range of crop species and varieties, farmers can increase the likelihood of having some crops that can withstand and adapt to changing climate conditions. If one crop fails due to unfavorable conditions, others may still thrive, reducing the overall vulnerability of the agricultural system.

b) Risk mitigation

Climate change brings increased uncertainty and risks to agriculture, including changing rainfall patterns, temperature extremes, and emerging pests or diseases. Crop diversity helps mitigate these risks by spreading them across different crops. If a particular crop is susceptible to a climate-related threat, other crops in the system can provide a buffer, reducing the likelihood of complete crop failure. This risk diversification helps farmers adapt to climate variability and minimize the economic and food security impacts of extreme events.

c) Pest and disease management

Crop diversity plays a crucial role in managing pests and diseases. Monoculture systems, where a single crop is grown over large areas, are more susceptible to pest outbreaks and the spread of diseases. By contrast, diversified cropping systems disrupt pest and disease cycles, making it more difficult for pests and pathogens to establish and spread. Additionally, different crop species may have varying resistance or tolerance to specific pests or diseases. By incorporating diverse crops, farmers can reduce the reliance on chemical pesticides and improve overall pest and disease management.

d) Improved nutrient management

Crop diversity can contribute to improved nutrient management in agricultural systems. Different crops have different nutrient requirements and uptake patterns. By rotating or intercropping crops with different nutrient demands, farmers can optimize nutrient use and reduce the risk of nutrient imbalances or depletion. Crop rotation, for example, allows for the build-up of soil organic matter and nutrient cycling, enhancing soil fertility and reducing the need for external inputs. Improved nutrient management supports sustainable and resilient agricultural production in the face of climate change.

Soil testing and nutrient calibration is a critical practice for improved nutrient management hence it is imperative to build soil nutrient databases for fertilizer calibration. However, farmers, especially smallholder farmers, have not adopted soil testing technologies. However, a limiting step for adoption of soil testing technologies is improved access to testing by decentralization of services with investments in mobile laboratories at sub-national level.

e) Soil health and ecosystem services

Crop diversity promotes soil health and the provision of ecosystem services. Different crops have different root structures and nutrient cycling capacities, leading to improved soil structure, organic matter content, and nutrient availability. Diverse cropping systems, such as intercropping or agroforestry, enhance soil biodiversity, microbial activity, and nutrient cycling processes. These practices contribute to improved soil fertility, water-holding capacity, and overall soil health. Healthy soils provide a robust foundation for agricultural resilience, nutrient cycling, water filtration, and carbon sequestration.

f) Food and nutrition security

Crop diversity is vital for ensuring food and nutrition security in the face of climate change. By cultivating a diverse range of crops, farmers can provide a wider variety of nutritious foods, reducing dependence on a few staple crops. Crop diversity contributes to a balanced and diverse diet, enhancing food security and resilience to climate-related shocks that may impact specific crops. It also helps preserve traditional and indigenous food crops, maintaining cultural heritage and dietary diversity.

g) Climate change mitigation

Crop diversity can contribute to climate change mitigation efforts. Diverse cropping systems, especially those incorporating perennial crops or agroforestry, sequester more carbon in vegetation and soils compared to monocultures. Increased carbon sequestration helps offset greenhouse gas emissions, mitigating climate change. Additionally, diverse cropping systems may have more efficient resource use, such as water or nutrients, reducing the environmental footprint of agriculture.

In summary, crop diversity is a valuable strategy for climate change adaptation in agriculture. It enhances the resilience of agricultural systems, reduces risks associated with climate variability, improves nutrient cycling, aids in pest and disease management, preserves genetic resources, and supports various ecosystem services. By embracing crop diversity, farmers can build more adaptable and sustainable agricultural systems capable of withstanding and thriving in the face of climate change.

3.4.7 Biotechnology for climate change adaptation of crops

New varieties developed through biotechnology offer several benefits for climate change adaptation in agriculture.

a) Enhanced stress tolerance

Biotechnology enables the development of crop varieties with enhanced stress tolerance, such as drought tolerance, heat tolerance, or resistance to pests and diseases. Through genetic engineering techniques, specific genes responsible for stress tolerance can be introduced into crop plants. These new varieties can better withstand adverse climate conditions, helping farmers adapt to changing environmental conditions associated with climate change. For example, drought-tolerant crops can maintain productivity even with reduced water availability.

b) Improved yield and productivity

Biotechnology can contribute to improved crop yield and productivity. New varieties can be genetically modified to have increased resistance to pests and diseases, reducing yield losses caused by infestations. Biotechnology also allows for the development of crops with improved agronomic traits, such as faster growth, increased nutrient uptake efficiency, or better adaptation to specific environmental conditions. By increasing crop yield and productivity, biotechnology helps ensure food security and supports farmers in adapting to the challenges posed by climate change.

c) Reduced environmental impact

Biotechnology can help reduce the environmental impact of agriculture. Genetically modified crops with built-in pest resistance require fewer chemical pesticides, reducing chemical use and its associated environmental risks. This can minimize the pollution of water bodies, harm to non-target organisms, and overall ecological disruption. By reducing the reliance on chemical inputs, biotechnology promotes more sustainable farming practices and contributes to environmental stewardship.

d) Enhanced nutritional quality

Biotechnology can be used to develop crops with improved nutritional quality. For instance, genetic engineering techniques can be employed to increase the content of essential nutrients, such as vitamins or minerals, in crops. This can help address nutritional deficiencies and improve human health. Additionally, biotechnology can reduce the presence of anti-nutritional factors or allergens in crops, making them safer and more accessible to consumers. Improved nutritional quality in crops supports climate change adaptation by enhancing the nutritional resilience of communities.

e) Expanded crop range

Biotechnology allows for the expansion of the crop range to new environments and regions. Through genetic modification, crop plants can be engineered to be more adaptable to different climates, soil conditions, or biotic stresses. This opens opportunities for agricultural production in areas previously unsuitable for certain crops. By expanding the crop range, biotechnology enables farmers to diversify their production and adapt to changing climate conditions, reducing the dependence on a limited set of crops, and increasing agricultural resilience.

f) Conservation of genetic resources

Biotechnology plays a role in the conservation and utilization of genetic resources. By introducing desirable traits into crop plants through genetic engineering, unique genetic resources can be preserved and utilized effectively. This is particularly relevant for crops with valuable genetic traits that are vulnerable to climate change or threatened by habitat loss. Biotechnology allows for the incorporation of these traits into new varieties, ensuring their conservation and utilization for future generations.

g) Rapid breeding and trait introduction

Biotechnology offers a more efficient and accelerated approach to crop breeding and trait introduction. Traditional breeding methods often take many years to develop new varieties with desired traits. Biotechnology techniques, such as genetic modification or gene editing, enable more precise and targeted trait introduction, significantly reducing the time required for breeding. This allows for faster development and deployment of climate-resilient crop varieties, facilitating timely adaptation to changing environmental conditions.

Overall, new varieties developed through biotechnology provide valuable tools for climate change adaptation in agriculture. They offer enhanced stress tolerance, improved yield and productivity, reduced environmental impact, enhanced nutritional quality, expanded crop range, conservation of genetic resources, and accelerated breeding processes. These benefits can help farmers mitigate the impacts of climate change, ensure food security, and promote sustainable agriculture.

3.4.8 Ecological pest management

Ecological pest management, also known as integrated pest management (IPM), offers several benefits for climate change adaptation in agriculture.

a) Reduced reliance on chemical pesticides

Ecological pest management focuses on minimizing the use of chemical pesticides and instead emphasizes the use of natural and environmentally friendly pest control strategies. By reducing pesticide applications, farmers can mitigate the negative impacts of chemical pesticides on the environment, including water pollution, harm to beneficial insects and organisms, and the development of pesticide resistance. This promotes a more sustainable and resilient agricultural system in the face of climate change.

b) Preservation of beneficial insects and biodiversity

Ecological pest management seeks to conserve and promote beneficial insects and organisms that naturally control pests. By minimizing the use of broad-spectrum pesticides, which can harm beneficial insects, farmers can foster a diverse and balanced ecosystem within their fields. Beneficial insects, such as ladybugs, predatory wasps, or parasitic nematodes, can play a crucial role in controlling pest populations. Preserving biodiversity and supporting natural pest control mechanisms enhances the resilience of agricultural systems to climate-related pest outbreaks.

c) Integrated approach to pest management

Ecological pest management adopts an integrated approach that combines multiple pest control methods. It involves monitoring pest populations, setting action thresholds, and employing a range of preventive and control measures. These measures may include cultural practices (e.g., crop rotation, intercropping), mechanical methods (e.g., trapping, physical barriers), biological control (e.g., releasing beneficial organisms), and targeted pesticide use only when necessary. This integrated approach provides flexibility and adaptability to changing climate conditions and pest dynamics.

d) Adaptability to changing pest dynamics

Climate change can influence the population dynamics of pests, including their distribution, abundance, and timing. Ecological pest management offers a flexible framework to adapt to these changing pest dynamics. By monitoring pest populations and understanding their biology, farmers can adjust their pest control strategies accordingly. This adaptability helps farmers manage emerging pests or changes in pest pressure associated with climate change, reducing the risk of crop losses and ensuring agricultural productivity.

e) Reduced economic losses

Ecological pest management helps minimize economic losses caused by pest damage. By employing preventive measures, such as crop rotation or the use of resistant crop varieties, farmers can reduce pest infestations and subsequent yield losses. Early pest detection and intervention enable timely control measures, preventing pest outbreaks and reducing crop damage. By minimizing crop losses, ecological pest management contributes to the economic viability of farming operations, which is crucial for adapting to the challenges posed by climate change.

f) Improved environmental resilience

Ecological pest management enhances the environmental resilience of agricultural systems. By promoting biodiversity, conserving beneficial insects, and reducing chemical pesticide use, it helps maintain a healthy and resilient ecosystem. A diverse and balanced ecosystem is better equipped to withstand and recover from climate-related disturbances, such as extreme weather events or pest outbreaks. Ecologically resilient agricultural systems contribute to the overall adaptation and sustainability of farming in the face of climate change.

g) Long-term sustainability

Ecological pest management aligns with the principles of sustainable agriculture. By minimizing the use of chemical inputs, promoting natural pest control mechanisms, and considering the ecological context of pest management, it supports the long-term sustainability of agricultural production. Sustainable agricultural practices ensure the conservation of natural resources, minimize negative environmental impacts, and maintain the health and productivity of agricultural ecosystems. Ecological pest management contributes to the resilience of farming systems and helps farmers adapt to the challenges posed by climate change in a sustainable manner.

Overall, ecological pest management offers multiple benefits for climate change adaptation in agriculture. It reduces reliance on chemical pesticides, preserves beneficial insects and biodiversity, adopts an integrated approach to pest management, adapts to changing pest dynamics, reduces economic losses, improves environmental sustainability.

3.4.9 Seed and grain storage

Seed and grain storage plays a crucial role in climate change adaptation in agriculture, providing several benefits.

a) Ensuring food security

Proper seed and grain storage facilities help ensure food security by preserving harvested crops for extended periods. Climate change brings increased uncertainty and the risk of extreme weather events, such as droughts, floods, or storms, which can damage crops in the field or during transportation. Adequate storage facilities protect harvested seeds and grains from these risks, ensuring a stable food supply and reducing the vulnerability of farmers and communities to climate-related crop losses.

b) Preservation of genetic diversity

Seed storage enables the preservation of genetic diversity in agricultural crops. Genetic diversity is crucial for adapting to changing climate conditions as it contains a wide range of traits that can contribute to resilience and adaptation. By storing a diverse collection of seeds, including traditional or locally adapted varieties, farmers and seed banks can safeguard valuable genetic resources. This diversity provides a resource for breeding programs and the development of climate-resilient crop varieties in the face of changing environmental conditions.

c) Seed quality and viability

Proper seed storage helps maintain seed quality and viability over time. Seeds are living entities, and their storage conditions significantly influence their germination rate and overall quality. Controlled storage environments, such as cool, dry, and well-ventilated facilities, can extend the longevity of seeds, ensuring high germination rates and seed vigor. This is particularly important in the context of climate change, as farmers may need to replant crops more frequently due to changing weather patterns or the emergence of new pest and disease pressures.

d) Risk management

Seed and grain storage facilities serve as risk management tools for farmers. They provide a buffer against unexpected events, such as crop failures, market fluctuations, or disruptions in the supply chain. By storing surplus seeds or grains, farmers can mitigate the impacts of climate-related crop losses and maintain a degree of control over their production and income. Storage allows farmers to time their sales strategically, taking advantage of better market conditions or waiting for higher prices, thus enhancing their financial resilience.

e) Local seed systems and self-sufficiency

Seed storage supports the development and maintenance of local seed systems, contributing to self-sufficiency and community resilience. Local seed systems rely on the exchange, saving, and reuse of seeds within a community or region. By storing locally adapted seeds, farmers can maintain their independence and reduce their dependence on external seed sources, especially in remote or vulnerable areas. Local seed systems foster agricultural diversity, traditional knowledge, and community empowerment, enhancing adaptation capacity in the face of climate change.

f) Business opportunities and value addition

Proper seed and grain storage facilities can create business opportunities and value addition for farmers. Improved storage technologies, such as hermetic storage bags or silos, can reduce post-harvest losses and maintain the quality of stored crops. This allows farmers to access premium markets, negotiate better prices, or process their grains into value-added products. Storage facilities enable farmers to store crops during periods of oversupply and sell them when prices are more favourable, enhancing their economic resilience and income generation potential.

g) Climate resilient farming practices

Seed and grain storage facilities support the adoption of climate-resilient farming practices. For example, storing seeds of different crop varieties allows farmers to experiment with new or drought-tolerant varieties that are better suited to changing climatic conditions. Additionally, seed storage facilitates crop diversification, enabling farmers to adapt their crop choices based on climate projections and market demands. This flexibility in crop selection contributes to overall agricultural resilience in the face of climate change.

In summary, seed and grain storage facilities are essential for climate change adaptation in agriculture. They contribute to food security, preserve crop diversity, manage risks associated with climate-related events, support local adaptation, enable future planting opportunities, and enhance market stability. By investing in proper storage infrastructure and techniques, farmers can build more resilient and adaptable agricultural systems in the face of climate change.

3.4.10 Selective breeding via controlled mating

Livestock disease management plays a critical role in climate change adaptation in agriculture, providing several benefits.

a) Animal health and welfare

Effective livestock disease management ensures the health and welfare of animals. Climate change can increase the prevalence and spread of certain diseases, as changing environmental conditions may favor the survival and transmission of pathogens. By implementing disease prevention measures, such as vaccination programs, biosecurity protocols, and proper hygiene practices, farmers can protect their livestock from diseases and minimize their suffering. Maintaining the health and welfare of animals is crucial for sustainable livestock production and resilience in the face of climate change.

b) Reduced economic losses

Livestock diseases can cause significant economic losses for farmers. They lead to reduced productivity, including decreased milk production, weight loss, decreased fertility, and increased mortality rates. By implementing effective disease management strategies, farmers can reduce the impact of diseases on their livestock, thereby minimizing economic losses. This is particularly important in the context of climate change, where farmers may already face additional challenges related to extreme weather events, changing disease patterns, or emerging infectious diseases.

c) Enhanced food security

Livestock plays a vital role in global food security by providing meat, milk, eggs, and other animal-derived products. Livestock diseases can pose a threat to food security by reducing animal productivity and potentially causing supply disruptions. Effective disease management practices help ensure a stable and secure supply of livestock products, contributing to overall food security. By protecting the health of their animals, farmers can maintain a consistent production of nutritious food for local consumption and markets.

d) Improved livestock resilience

Climate change patterns and challenges for livestock farming, including increased heat stress, altered rainfall patterns, and shifts in disease vectors. Disease management contributes to livestock resilience by reducing the susceptibility of animals to diseases and strengthening their ability to cope with changing environmental conditions. This can be achieved through selective breeding for disease resistance, improving nutrition and animal husbandry practices, and implementing early detection and intervention strategies. Resilient livestock populations are better able to adapt to the challenges posed by climate change, ensuring the long-term sustainability of livestock farming.

Lesotho is already introducing, *al beit* at its infancy, an artificial insemination programme as a critical technology for climate change adaptation. This allows farmers to manage the lambing period for small stock ensuring that they ewes conceive and lamb within a defined period. Thus it is critical to upscale this technology through appropriate investment and capacity building in critical institutions.

e) Environmental sustainability

Livestock disease management promotes environmental sustainability in agricultural systems. Effective disease prevention measures, such as proper waste management, biosecurity protocols, and responsible use of veterinary medicines, minimize the impact of livestock farming on the environment. By preventing disease outbreaks, farmers can avoid the need for excessive use of antibiotics or other chemicals, reducing the risk of environmental contamination and the development of antimicrobial resistance. Sustainable disease management practices contribute to the overall environmental resilience of livestock production systems.

f) Enhanced livelihoods and rural development

Livestock farming is a significant source of income and livelihood for many rural communities. Disease management helps safeguard the livelihoods of farmers by ensuring the productivity and profitability of their livestock enterprises. By protecting their animals from diseases, farmers can maintain a stable income and sustain their agricultural activities. Healthy and productive livestock also contribute to rural development by generating employment opportunities, supporting local economies, and enhancing the resilience of farming communities to climate change impacts.

g) One health approach

Livestock disease management aligns with the One Health approach, which recognizes the interconnectedness of human, animal, and environmental health. Diseases that affect livestock can have zoonotic potential, meaning they can transmit from animals to humans. By effectively managing livestock diseases, farmers contribute to the prevention and control of zoonotic diseases, protecting both human and animal populations. This integrated approach to disease management promotes the well-being of animals, humans, and the environment, creating a more resilient and sustainable agricultural system.

In summary, effective livestock disease management is crucial for climate change adaptation in agriculture. It improves livestock health and resilience, reduces production losses, promotes sustainable resource use, protects livelihoods, ensures food security and safety, and contributes to climate change mitigation. By implementing comprehensive disease management strategies, farmers can enhance the resilience and sustainability of livestock production systems in the face of climate change challenges.

3.4.11 Sustainable farming systems

Mixed farming systems, which involve the integration of crop cultivation and livestock rearing, offer several benefits for climate change adaptation in agriculture.

a) Increased resilience to climate variability

Mixed farming systems are more resilient to climate change impacts compared to monoculture systems. The combination of crops and livestock diversifies the farm's income sources, reducing the vulnerability to market fluctuations and climate-related risks. If one enterprise is affected by adverse climate conditions, the other may remain unaffected or less affected, providing a buffer against income losses. This diversification enhances the overall resilience of the farming system to climate variability.

b) Nutrient cycling and soil health

Mixed farming promotes nutrient cycling and improves soil health. Livestock manure can be used as organic fertilizer for crop cultivation, replenishing soil nutrients and improving soil fertility. The integration of crops and livestock allows for the recycling of organic matter and nutrients. For example, crop residues and by-products can be fed to animals, and their manure can be returned to the land as fertilizer. This closed-loop nutrient cycling system reduces the reliance on synthetic fertilizers, improves soil structure, and enhances soil moisture retention, thus contributing to climate change adaptation.

c) Efficient resource utilization

Mixed farming optimizes the utilization of available resources. Crop residues, cover crops, and forages that are unsuitable for human consumption can be used as feed for livestock, minimizing waste and maximizing resource efficiency. Livestock convert these low-value or surplus feed resources into valuable animal products, such as meat, milk, and eggs. This efficient use of resources contributes to sustainable agricultural practices and reduces the environmental footprint of farming operations.

d) Biodiversity and ecosystem services

Mixed farming systems support biodiversity conservation and provide ecosystem services. The combination of crops and livestock creates a diverse landscape that can harbour a variety of plant and animal species. This biodiversity promotes natural pest control, pollination, and soil health. By avoiding monoculture and providing diverse habitats, mixed farming systems contribute to the preservation of beneficial insects, birds, and other wildlife, which in turn support the resilience and stability of agricultural ecosystems.

e) Climate-smart agriculture

Mixed farming aligns with the principles of Climate-Smart Agriculture (CSA), which aims to increase agricultural productivity, enhance resilience, and reduce greenhouse gas emissions. The integration of crops and livestock within the same system allows for synergistic interactions that optimize resource use and minimize environmental impacts. Mixed farming systems can contribute to CSA goals by implementing practices such as agroforestry, rotational grazing, cover cropping, and diversified cropping patterns. These practices enhance climate change adaptation and mitigation in agriculture.

f) Risk spreading and livelihood security

Mixed farming systems spread risks and enhance livelihood security for farmers. By diversifying their production, farmers reduce their dependence on a single enterprise and spread the risks associated with climate variability. If a particular crop fails or suffers from adverse weather conditions, income from livestock can provide a financial safety net. This risk-spreading aspect of mixed farming systems helps farmers maintain their livelihoods, especially in the face of uncertain climate conditions.

g) Social and economic benefits

Mixed farming contributes to rural development and community well-being. It provides opportunities for additional employment, as the integration of crops and livestock often requires more labor compared to specialized systems. Mixed farming systems foster local knowledge, skill-sharing, and community collaboration, enhancing social cohesion and resilience. Additionally, the availability of diverse agricultural products from mixed farming systems promotes local food security, reduces reliance on external sources, and supports the local economy.

In summary, mixed farming systems offer numerous benefits for climate change adaptation in agriculture. They enhance resilience to climate variability, promote nutrient cycling and soil health, optimize resource utilization, support biodiversity conservation, align with Climate Smart Agriculture principles, spread risks, and provide social and economic benefits to farmers.

3.4.12 Farmer Field Schools

Farmer Field Schools (FFS) are participatory and experiential learning platforms that offer several benefits for climate change adaptation in agriculture.

a) Knowledge and skills development

FFS provide farmers with opportunities to gain knowledge and develop practical skills related to climate change adaptation in agriculture. Through interactive learning sessions, demonstrations, and field-based activities, farmers learn about climate-smart practices, such as sustainable soil management, water conservation, crop diversification, agroforestry, and integrated pest management. FFS empower farmers to acquire new techniques, adapt their farming practices, and make informed decisions to mitigate and adapt to climate change impacts.

b) Local context and farmer empowerment

FFS are tailored to the local context, considering the specific climate conditions, agro-ecological settings, and socio-economic factors of the region. This localized approach ensures that farmers receive relevant and practical information that can be applied to their specific circumstances. By actively involving farmers in the learning process and encouraging their participation, FFS empower them to take ownership of their adaptation strategies and become agents of change in their communities. This empowerment fosters resilience and adaptive capacity among farmers.

c) Sharing of local knowledge and best practices

FFS create a platform for farmers to exchange local knowledge, share experiences, and discuss best practices. The participatory nature of FFS allows farmers to learn from each other, capitalize on traditional wisdom, and adapt successful techniques to their own farming systems. This peer-to-peer learning approach strengthens social networks, encourages innovation, and enhances the collective learning capacity of farming communities. By fostering knowledge sharing, FFS contribute to the development of context-specific climate change adaptation strategies.

d) Adaptive decision-making

FFS equip farmers with the skills to make informed and adaptive decisions in the face of climate change. Through hands-on activities, farmers learn to observe and interpret environmental cues, monitor crop and soil conditions, and assess risks and opportunities. This experiential learning approach helps farmers develop critical thinking, problem-solving, and decision-making skills. By understanding the principles of agroecosystems and climate dynamics, farmers can adjust their farming practices and management strategies to optimize productivity and resilience under changing climatic conditions.

e) Enhanced resilience and risk management

FFS contribute to the enhancement of farmers' resilience and their ability to manage climate-related risks. By diversifying their knowledge base and adopting climate-smart practices, farmers can reduce vulnerability to climate change impacts. FFS promote the integration of climate risk management strategies, such as early warning systems, climate-informed crop planning, insurance schemes, and post-harvest management techniques. These risk management approaches enable farmers to minimize losses, protect their livelihoods, and build adaptive capacity in the face of climate uncertainties.

f) Gender inclusivity and social equity

FFS promote gender inclusivity and social equity in agricultural communities. By actively involving women and marginalized groups in FFS, equal opportunities for learning and participation are created. This inclusivity helps address gender disparities, recognizes the diverse roles and knowledge of different community members, and promotes social equity. FFS empower women farmers by providing them with skills, knowledge, and decision-making capabilities, contributing to the overall resilience and adaptive capacity of farming communities.

g) Scaling up of climate-smart practices

FFS can facilitate the scaling up of climate-smart practices at the community and regional levels. As farmers gain knowledge and skills through FFS, they become potential multipliers of good practices within their communities. By sharing their experiences and promoting climate-smart techniques, farmers can influence others to adopt sustainable farming methods. This peer-to-peer extension approach facilitates the dissemination of climate change adaptation practices, leading to broader adoption and the potential for transformative change in agricultural systems. Overall, FFS provide a valuable platform for climate change adaptation in agriculture, offering farmers the necessary tools, knowledge, and support to mitigate risks, improve productivity, and build resilience in the face of a changing climate.

3.5 Criteria and process of technology prioritisation

There is a broad variety of available CCA technologies for the water and agriculture sector in Lesotho. Some of them are already in place whereas others are good practices from different countries that could be beneficial for Lesotho, too. However, the individual technologies can vary largely in the extent to which they are appropriate for addressing specific factors of vulnerability. Therefore, the purpose of this TNA study is to systematically assess the identified technologies and finally assist decision-makers in the appraisal and prioritization of CCA technologies. The approach used for this TNA is based on a Multi Criteria Analysis (MCA) that reflects the variety of aspects that need to be considered for the selection of CCA technologies. Conducting an MCA entails a thorough assessment of the technologies vulnerability under different viewpoints, resulting in individual matrices for each factor of vulnerability. The assessment of pre-selected technologies was based on their contribution to sustainable development goals and to adaptation in light of climate change impact scenarios for the Lesotho. The criteria on which the assessments were based were decided involving a wider group of stakeholders and assessing strategic national documents including policies and strategic plans. The criteria adapted for prioritization of adaptive technologies (adelphi/DevAlt, 2018) were used.

Each technology was scored on the given criteria. In addition, the weighting of the criteria was done through extended stakeholder consultation while keeping in context of the scoring of each technology on the criteria. The weights for each of the criterion are given in the last row of Table 6. MCA was used for ranking and prioritization of the listed technologies in the agriculture sector. The criteria informing the prioritization of the technologies in the agriculture and water sector included considerations of the eight variables (Table 2).

Table 2. Criteria for prioritizing adaptation technologies in the agriculture sector. Modified from Clements et al (2011).

Criteria Category	Description	Code	Code Description	Criteria	Scoring Range
Cost	The criteria encompass the inputs that are expected to be associated with technology transfer. Costs of technology transfer are a major factor when choosing technology alternatives and need to be balanced by the benefits obtained from the alternatives.	**A1**	Cost to set up the technology	Low cost of set-up including the costs of importation and installation.	0 - 100
		A2	Cost to operate the technology	Low cost for maintenance/ operation and other running costs of the technology over time.	0 - 100
Benefits: The benefits criteria encompass the benefits associated with the climate technology transfer. These move beyond the quantifiable economic benefits but aim to encompass other areas such as economic, institutional and political, environmental, social, climate-related, and technology related criteria.					
Economic Benefits	Economic criteria represent the economic benefits to be gained from choosing technology alternatives. Climate adaptation technologies encourage private investment to drive local innovation and ensure financial sustainability of the product. It improves general economic performance in the agriculture sector, that result from increasing productivity and market development.	**B1**	Involve and encourage corporate sector / industries to take up, support and promote technology as part of corporate social responsibility to ensure the financial sustainability of the technology and its use.	Potential to improve farmer's income.	0 - 100
		B2	Improving economic performance in that sector through increased productivity etc. farmer income and ability to reinvest		0 - 100

Criteria Category	Description	Code	Code Description	Criteria	Scoring Range
Institutional Benefits	The criteria look at the institutional and political factors associated with the decision to choose one adaptation technology over another alternative. A technology alternative should ideally be aligned with the country's national adaptation plan and national development goals. This is to ensure that technology transfer actions are streamlined with the priorities set by the government in the national adaptation plan, and in working towards the development goals as set out in the National Strategy Development Plan. Furthermore, introduction of new technologies should not require an overhaul of current regulatory and physical infrastructure. Thus, as many regulations and laws supporting a technology alternative should already be in place to support ease of implementation.	C1	Ease of implementation, e.g. can be included in existing government programme or funding scheme including degree of coherence with ICM Project	Potential of the technology to be easily implemented	
		C2	Single Identified Agency for management-Convergence or viable mechanisms for coordination among various ministries /departments and other stakeholders	Extent to which technology has been included in the National Development Agenda	0 - 100
		C3	Coherence with national development policies and priorities		0 - 100
Social Benefits	This set of criteria address the social aspects that must be considered when choosing a technology alternative. Since adaptation to climate change affects society, technologies to remediate impacts should also leave positive benefits for the local population. These could encompass effects that contribute to poverty reduction, inequity reduction, improvements to health, and preserving cultural heritage.	D1	Addresses needs for essential food and water requirements for human health and nutrition	Extent to which the technology addresses the SDGs	0 – 100
		D2	Technology should aim to reduce inequity between gender and ensuring equity	Extent to which technology is culturally and socially acceptable.	0 – 100
			Contribution to social and sustainable development	Extent to which the technology addresses the SDGs	0 – 100

Criteria Category	Description	Code	Code Description	Criteria	Scoring Range
		D3	(benefit to society e.g. gender sensitive, poverty alleviation, increasing food and water security)		
Environmental Benefits	Environmental benefits need to be carefully considered when choosing technology alternatives. Environmentally detrimental technologies work against protecting the integrity of nature and its resources and therefore aspects such as biodiversity protection, protection of environmental resources and support to ecosystem services need to be considered.	E1	Contribution of the technology to protect and sustain aquatic /terrestrial ecology. Protecting the diversity (agro /aquatic) where technology adaptation takes place.	Potential to support ecosystem services.	0 - 100
		E2	Recycling /Reuse of water and/or substitute to domestic water supply		0 - 100
Climate Benefits	Climate-related criteria are important to take in consideration when choosing technology alternatives as the aim of technology transfer is to mitigate the impacts of climate change. The two main criteria encompass the adaptation and mitigation potential of climate technologies. These are the potential for the technology to reduce vulnerability and build resilience amongst communities to climate impacts and any reduction in direct greenhouse gas emissions.	F1	Efficiency of the technology to reduce vulnerability to climate change impacts. E.g. Strengthening current standards of living so that in the face of adversity, households may be able to cope with the climate shock	Potential to reduce vulnerability and increase the ability of vulnerable groups to protect them against climate change disturbance	0 - 100
		F2	Reduction in GHG emissions, e.g. through usage of renewable energies or an energy efficiency measure	Potential mitigation benefits from any given climate technology is advantageous	0 - 100

Criteria Category	Description	Code	Code Description	Criteria	Scoring Range
Technology Related Benefits	This set of criteria covers basic elements of technology transfer. Assuming that climate technologies should be readily accepted and dispersed within the affected population, rate of technology diffusion which is tied closely to farmer acceptance is a crucial criterion to consider.[3] Moreover, the technology's efficiency in relation to other alternatives must also be considered and the main aspects that are examined relate to the technology's maturity and effectiveness in helping populations adapt to climate change.	G1	Local experience exists, technology can be operated by local operators without needing external support, does not conflict with existing processes, easier technology diffusion and farmer acceptance	The potential of how efficient and effective the technology is in achieving the desired results	0 – 100
		G2	Technology helps in increasing beneficial output per unit of water /land i.e. looking at engineering and agronomic aspects in conjunction, increasing resource (Land /water) use efficiency		0 - 100

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[3] Rate of diffusion for a technology prioritised in the TNA should ideally be low at this point. The whole point of the TNA is to find reasons or barriers for low diffusion and to devise measures to overcome the barriers, leading to high diffusion and deployment.

For each adaptation technology, the agriculture / water sector, stakeholders scored the technology on the basis of two broad categories: Costs and Benefits (8 criteria categories) as detailed in Table 2. The stakeholders applied 16 Codes on a scale of 0 – 100. It was difficult determining actual technology costs hence stakeholders decided to use a scoring system of 0 – 100. On the cost category zero (0) is the preferred score and 100 is the worst cost scenario. In the contrast on the benefit side, zero (0) is least preferred while 100 is the best case scenario in implementing and operating the technology. In the few cases where the stakeholders could not agree on a score by consensus, a majority decision was taken. Scores were captured into an Excel spreadsheet (Table 3).

To compare the scoring for the different criteria a relative scoring scale was used. To determine the relative score when a lower value is preferable the following formula was used

$$X_{Rel} = 100*(X_{max} - X)/ (X_{max} – X_{min})$$

Where,
X_{Rel} is the relative score
X is the criterion score
X_{max} is the highest criterion score
X_{min} is the lowest criterion score

When a higher value is preferable

$$X_{Rel} = 100*(X- X_{min})/ (X_{max} – X_{min})$$

Where
X_{Rel} is the relative score
X is the criterion score
X_{max} is the highest criterion score
X_{min} is the lowest criterion score

All technology options were then scored against all criteria (Table 4). Each criterion was assigned a weight to reflect the weight of importance that stakeholders assign to each of the specific criterion. The criteria were weighted and the scores against all criteria were then compared. Thereafter the technologies were ranked based on the weighted total scores (Table 5).

To investigate the sensitivity of technology ranking on allocated weights, the weight assigned to each criterion, expert opinion was used to reassess each one by increasing the climate effect weight from a total weighting of 20% (Resilience = 15%; Mitigation co-benefit = 5%) to a total climate weighting of 45% (Resilience = 40%; Mitigation co-benefit = 5%) (Table 6). The overall weightings were then adjusted downwards for the following: costs, economic, efficiency and institutional and policy alignment (Table 6). The consensus approach of stakeholder consultations is not always objective or scientific and false impressions or misunderstanding about a particular aspect of a technology or analysis may shift the decision structures. More importantly, expert consultants have to be sensitive to appearing to be pushing a particular agenda or line of argument. In the instance, the first round of review consultations with the experts exposed a serious weakness in the weighting of the importance of climate change versus other variables. For example the climate change weight was significantly low despite climate change being the driving factor for adaptation initiatives. For example, stakeholders gave Conservation Agriculture a low score based on the implementation constraints and lack of proper equipment currently faced by farmers hence limiting adoption rates whereas the nature of the current limitations should theoretically work in its favour as it gives a basis for solving adoption challenges and promoting the technology. Consequently, we conducted a sensitivity analysis by changing the weightings in favour of climate change. The processes resulted in a shift and exchange of technology rankings. Thus based on the sensitivity analysis, the ranking of the adaptation options was changed.

Table 3. Actual scores for each agriculture sector technology against the criteria

Technologies	Costs		Benefits								
			Economic	Institutional/ Political		Social		Environmental	Climate related		Technological
	Cost to set up the technology	Cost to operate the technology	Improving farmer income	Aligned to national development policies	Replicability	Social acceptability	Contribution to sustainable development	Contribution to protect and sustain ecosystem services	Enhance resilience against climate change	Reduce GHG emissions	Efficiency
Climate change monitoring system	70	40	90	100	30	100	80	80	90	60	45
Seasonal to inter-annual prediction	90	90	90	90	50	60	80	80	95	95	60
Decentralised community run early warning systems	40	30	90	95	70	95	85	75	85	70	90
Index-based Climate insurance	90	60	95	90	90	75	85	80	80	80	95
Sprinkler irrigation	95	90	70	100	60	80	95	55	85	30	70
Drip irrigation	60	80	80	100	50	75	80	90	85	75	95
Rainwater harvesting	50	30	90	95	90	85	80	80	85	90	90
Slow-forming terraces	45	20	60	50	80	45	45	70	65	65	70
Conservation Agriculture	55	60	85	85	60	60	90	80	90	90	75
Integrated soil nutrient management	40	50	60	65	65	70	80	70	80	45	75
Crop diversification	65	40	65	80	50	45	75	70	95	75	70
New varieties through biotechnology	80	65	65	70	30	65	70	40	80	70	75
Ecological pest management	50	40	65	70	80	65	75	80	60	85	60
Seed and grain storage	40	30	70	70	90	80	75	65	70	80	80
Selective breeding via controlled mating	85	70	75	90	60	50	80	70	80	65	65
Livestock disease management	80	70	90	90	75	85		65	80	45	80
Mixed farming	30	20	50	75	65	80		70	80	70	70
Farmer field schools	60	50	65	85	75	70		70	80	85	65

Table 4. Relative scores for each agriculture sector technology against the criteria

			Benefits								
	Costs		Economic	Institutional/ Political		Social		Environmental	Climate related		Technological
Technologies	Cost to set up the technology	Cost to operate the technology	Improving farmer income	Aligned to national development policies	Replicability	Social acceptability	Contribution to sustainable development	Contribution to protect and sustain ecosystem services	Enhance resilience against climate change	Reduce GHG emissions	Efficiency
Climate change monitoring system	38	71	89	100	0	100	84	80	86	46	0
Seasonal to inter-annual prediction	8	0	89	80	33	27	84	80	100	100	30
Decentralised community run early warning systems	85	86	89	90	67	91	89	70	71	62	90
Climated Indexed Climate insurance	8	43	100	80	100	55	89	80	57	77	100
Sprinkler irrigation	0	0	44	100	50	64	100	30	71	0	50
Drip irrigation	54	14	67	100	33	55	84	100	71	69	100
Rainwater harvesting	69	86	89	90	100	73	84	80	71	92	90
Slow-forming terraces	77	100	22	0	83	0	47	60	14	53	50
Conservation Agriculture	62	43	78	70	50	27	95	80	86	92	60
Integrated soil nutrient management	85	57	22	30	58	45	84	60	86	47	60
Crop diversification	46	71	33	60	33	0	79	60	57	69	50
New varieties through biotechnology	23	36	33	40	0	36	74	0	57	62	60
Ecological pest management	69	71	33	40	83	36	79	80	0	85	30
Seed and grain storage	84	86	44	40	100	64	79	50	29	77	70
Selective breeding via controlled mating	15	29	56	80	50	9	84	60	57	54	40
Livestock disease management	23	29	89	80	75	73	0	50	57	23	70
Mixed farming	100	100	0	50	58	64	0	60	57	62	50
Farmer field schools	54	57	33	70	75	45	0	60	57	85	40

Table 5. Weighted total scores and ranks of technologies in the agriculture sector

	Costs		Benefits									Total score	Rank
			Economic	Institutional/Political		Social		Environmental	Climate related		Technological		
Technologies	Cost to set up the technology	Cost to operate the technology	Improving farmer income	Aligned to national development policies	Replicability	Social acceptability	Contribution to sustainable development	Contribution to protect and sustain ecosystem services	Enhance resilience against climate change	Reduce GHG emissions	Efficiency		
Rainwater harvesting	**690**	**1290**	**890**	**540**	**400**	**511**	**252**	**800**	**710**	**460**	**1350**	**7893**	**1**
Decentralised community run early warning systems	**850**	**1290**	**890**	**540**	**268**	**637**	**267**	**700**	**710**	**310**	**1350**	**7812**	**2**
Agricultural Climate insurance	**80**	**645**	**1000**	**480**	**400**	**385**	**267**	**800**	**570**	**385**	**1500**	**6512**	**3**
Drip irrigation	540	210	670	600	132	385	252	1000	710	345	1500	6344	4
Seed and grain storage	840	1290	440	240	400	448	237	500	290	385	1050	6120	5
Climate change monitoring system	380	1065	890	600	0	700	252	800	860	230	0	5777	6
Conservation Agriculture	620	645	780	420	200	189	285	800	860	460	900	5769	7
Mixed farming	1000	1500	0	300	232	448	0	600	570	310	750	5710	8
Integrated soil nutrient management	850	855	220	180	232	315	252	600	860	235	900	5499	9
Livestock disease management	230	435	890	480	300	511	0	500	570	115	1050	5081	10
Farmer field schools	540	855	330	420	300	315	0	600	570	425	600	4955	11
Crop diversification	460	1065	330	360	132	0	237	600	570	345	750	4849	12
Ecological pest management	690	1065	330	240	332	252	237	800	0	425	450	4821	13
Seasonal to inter-annual prediction	80	0	890	480	132	189	252	800	1000	500	450	4773	14
Slow-forming terraces	770	1500	220	0	332	0	141	600	140	265	750	4718	15
Selective breeding via controlled mating	150	435	560	480	200	63	252	600	570	270	600	4180	16
Sprinkler irrigation	0	0	440	600	200	448	300	300	710	0	750	3748	17
New varieties through biotechnology	230	540	330	240	0	252	222	0	570	310	900	3594	18
Criterion weight	10	15	10	6	4	7	3	10	15	5	15	100	

Table 6. Sensitivity analysis for technologies in the agriculture sector

Technologies	Costs		Benefits									Total score	Rank
			Economic	Institutional/Political		Social		Environmental	Climate related		Technological		
	Cost to set up the technology	Cost to operate the technology	Improving farmer income	Aligned to national development policies	Replicability	Social acceptability	Contribution to sustainable development	Contribution to protect and sustain ecosystem services	Enhance resilience against climate change	Reduce GHG emissions	Efficiency		
Decentralised community run early warning systems	**1700**	**430**	**445**	**360**	**201**	**455**	**267**	**350**	**1420**	**310**	**450**	**6388**	**1**
Rainwater harvesting	**1380**	**430**	**445**	**360**	**300**	**365**	**252**	**400**	**1420**	**460**	**450**	**6262**	**2**
Conservation Agriculture	**1231**	**215**	**390**	**280**	**150**	**135**	**285**	**400**	**1720**	**460**	**300**	**5566**	**3**
Integrated soil nutrient management	**1700**	**285**	**110**	**120**	**174**	**227**	**252**	**300**	**1720**	**237**	**300**	**5425**	4
Drip irrigation	1080	70	335	400	99	275	252	500	1420	345	500	5276	5
Mixed farming	2000	500	0	200	174	320	0	300	1140	310	250	5194	6
Climate change monitoring system	760	355	445	400	0	500	252	400	1720	230	0	5062	7
Seed and grain storage	1680	430	220	160	300	320	237	250	580	385	350	4912	8
Index-based Climate insurance	160	215	500	320	300	275	267	400	1140	385	500	4462	9
Seasonal to inter-annual prediction	160	0	445	320	99	135	252	400	2000	500	150	4461	10
Farmer field schools	1080	285	165	280	225	225	0	300	1140	425	200	4325	11
Crop diversification	920	355	165	240	99	0	237	300	1140	345	250	4051	12
Livestock disease management	460	145	445	320	225	365	0	250	1140	115	350	3815	13
Ecological pest management	1380	355	165	160	249	180	237	400	0	425	150	3701	14
Slow-forming terraces	1540	500	110	0	249	0	141	300	280	265	250	3635	15
Selective breeding via controlled mating	300	145	280	320	150	45	252	300	1140	270	200	3402	16
Sprinkler irrigation	0	0	220	400	150	320	300	150	1420	0	250	3210	17
New varieties through biotechnology	460	1	165	160	0	180	222	0	1140	310	300	2938	18
Criterion weight	20	5	5	4	3	5	3	5	40	5	5	100	

3.6 Results of technology prioritisation in the agriculture sector

Table 3 shows the actual scores agreed upon by the stakeholders for the technologies against the criteria. The higher the score for a benefit criterion, the greater the beneficial attributes of the technology as portrayed by that criterion. On the other hand, the bigger the score for the costs criteria, the higher the disadvantage of the technology. As shown in the table all scores ranged from 0 to 100.

The relative scores (Table 4) show the unordered technologies, criteria and relative scores. The results table shows clearly that all relative scores were in the range 0 – 100. For the benefit and cost criteria, zero (0) means the least benefit and undesirable cost while 100 means the greatest benefit and desirable benefit.

The weighted total scores and the prioritised technologies are presented in Table 5 which shows the ordered technologies, criteria, weighted scores, weighted total scores and the ranks. The results show that the three highest ranked technologies (with ranks 1 – 3) are: 1) Rainwater harvesting; 2) Decentralized community run early warning system; and 3) Index-based Climate Insurance. However, following the sensitivity analysis, the technologies were re-ranked as follows: 1) Decentralised community run early warning systems; 2) Rainwater harvesting; and 3) Conservation Agriculture. We thus, herein summarize the individual scoring for these technological solutions with abridged descriptions.

Chapter 4 Technology prioritisation for the water sector

4.1 Key climate change vulnerabilities in the water sector

Climate change poses potentially significant and negative vulnerabilities to the water sector in Lesotho. The Kingdom of Lesotho relies heavily on its water resources for various purposes, including agriculture, water transfer to South Africa, hydropower generation, and domestic use. Some key climate change vulnerabilities in the water sector of Lesotho include:

a) Decreased water availability

Climate change can lead to changes in precipitation patterns, resulting in decreased water availability in Lesotho. This can have severe implications for both rural and urban communities that depend on water for drinking, irrigation, and industrial purposes.

b) Increased water Stress

With reduced water availability and increased demand due to population growth and economic development, Lesotho may experience heightened water stress. This can lead to conflicts over water resources and exacerbate social and economic inequalities.

c) Altered hydrological patterns

Climate change can disrupt natural hydrological patterns, including changes in rainfall intensity and frequency. This can result in more frequent and severe floods or droughts, affecting water infrastructure, agricultural productivity, and the overall water supply system in the country.

d) Wetland degradation and reduced snowfall in the highlands

Lesotho's mountains are home to sub-alpine wetlands supported by summer rainfall and winter precipitation in the form of snow. The wetlands act as natural reservoirs, releasing water gradually over time to maintain perennial flow of streams and rivers especially the upper reaches of the Senqu River Basin. However, soil erosion and land degradation due to overgrazing, and rising temperatures both compounded by climate change have led to degradation of the wetland ecosystem. Climate change is also projected to increase the temperatures in the highlands which will result in reduced snowfall. This reduces the capacity of these natural reservoirs, impacting perennial flow of streams and downstream water availability during the dry season.

e) Water quality concerns

Climate change can affect water quality by altering the temperature, flow, and chemical composition of water bodies. Changes in water quality can have adverse effects on aquatic ecosystems, human health, and the functioning of water treatment and supply systems.

f) Impact on hydropower generation

Hydropower generation is a critical component of Lesotho's energy budget with positive contributions to the climate change mitigation commitments of the nation. However, changes in water availability and hydrological patterns can affect the reliability and efficiency of hydropower plants, leading to energy shortages and increased dependence on alternative energy sources.

To address these vulnerabilities, it is crucial for Lesotho to implement adaptive measures and strategies, including sustainable water management practices, infrastructure development, and climate-resilient policies. Collaborative efforts with neighbouring countries especially the members of the Orange Senqu River and international partners can also help in managing shared water resources effectively and mitigating the impacts of climate change on the water sector.

4.2 Decision context

The relevant policies and national development plans were discussed in section 1.2 and were used as a basis to prioritise sectors. The National Adaptation Programme of Action (NAPA) 1997, the Lesotho Water and Sanitation Policy 2007 and Water Act 2008 are among the key documents that were used to identify technologies in the water sector. The Lesotho NAPA process identified and prioritised the eleven adaptation activities for implementation in the various vulnerability zones to address the adaptation needs of communities within and seek to build capacity within designated vulnerable communities with a hierarchy of importance prioritizing Village Water Supply for Communities especially in the southern Lowlands (Option 5) read together with the second statement of Lesotho Water and Sanitation Policy 2007 on Water Supply and Sanitation Services: "Ensure access to a sustainable supply of potable water and basic sanitation services for all Basotho". In addition, the decision structure sought to implement the letter and spirit of the Water Act 2008 which creates a legal context for integrated catchment management (water, ecosystems; climate adaptation, mitigation and resilience; governance and general economic development) and the objectives of ICM (reduce catchment degradation) and codifies elements of SDG on sustainable water availability. In the backdrop of the NAPA, the NCCP 2017–2027 enjoins every sector and every role player to pursue ways and means to enhance climate change adaptation and mitigation measures. Thus, the NCCP 2017-2027 implicitly calls for streamlining climate change adaptation in the water sector.

Furthermore, NSDP II emphasizes that water is a key determinant of economic growth, which can drive sustainable development because of its potential to contribute to the development of significant investments, enabling growth in other sectors and stimulating job opportunities. The relative abundance of water, coupled with the Government’s sustained commitment, has contributed to Lesotho’s high rates of access to safe water in Sub-Saharan Africa. Despite this, the country remains vulnerable to the shocks of regular and recurrent floods and droughts. The floods in 2011 were the largest on record since the 1930s, while the drought in 2015–16 is the driest in living record. The prospects of an increasingly unpredictable and variable climate have profound implications for the structure of the economic prospects of Lesotho. Thus, a focus on adaptation technologies for the water sector is imperative now and into the future. This analysis gives direction to the national development goals and identifies important options to consider the sectoral risks from climate change.

The centrality of agriculture in the economy of Lesotho brings the issues of water resources to the fore of climate change adaptation technologies for the water sector. Statement 3 of NCCP 2017-207 calls for Climate-smart Agriculture as a tool to build national adaptive capacity in the agriculture sector in response to climate change hazards. Consequently, we used the Climate Smart Agriculture Investment Plan (CSAIP 2018) and the Irrigation Policy aspirations to support the prioritization of the water sector.

Lesotho’s water and sanitation policy is based on the recognition of a need for a holistic and sustainable water resources management and development approach, ensuring as wide a participation of water stakeholders as possible and treating the resource as an economic, environmental and social good. Thus, in prioritizing the Water Sector, we aim to make a clarion call to all sectors of the society to join hands in managing, conserving, and protecting this valuable resource in order to satisfy our present needs as well as those of future generations. Of vital importance are controlling land degradation, good rangeland management practices, wetlands conservation, controlling pollution and invasive alien species.

4.3 Overview of existing technologies in the water sector

The issue of water security, availability and access is enshrined in the Lesotho Water and Sanitation Policy 2007 and it's the Water Act 2008 read together with different national policies and plans such as the NSDP II, CSAIP and Irrigation Policy. In 1986, the Lesotho government signed a bilateral treaty with the Republic of South Africa as a basis for cooperation in developing the Lesotho Highland Development Project (LHDP). Although the project has, on the main, been focused on transfer of water to South Africa, it brought several water resources development initiatives in Lesotho including the hydropower generation at 'Muela in the Botha-Bothe District. In addition, in times of crisis, the 'Muela Dam has been used to transfer water into the Mohakare River supply the lowlands towns from Botha-Bothe to Maseru albeit with high inefficiency with regard to drawing out the water out of the river channel. Sequel to the LHDP treaty of 1986, Lesotho has developed a comprehensive lowlands water scheme within the Mohokare and the Makhaleng river basins. These entail the construction and operation of the Metolong scheme and its network supplying Maseru, Berea, Roma and Morija. Subsequent phases of the Lowlands Water Scheme are in advanced planning stages.

In addition to hydrological monitoring of the three river basins, Mohokare, Makhaleng and Senqu, the Department of Water Affairs has developed capacity for survey and regulation of the underground water resources in terms of the Lesotho Water and Sanitation Policy as well as the Water Act as the principal law. In the context of the policy and law, the Water Commission has been promulgated for coordination of all water resources issues in Lesotho and the Lesotho Irrigation Policy has been developed under the Ministry of Agriculture and Food Security.

Six typologies are used here to define the adaptive function to which these technologies and practices contribute. For each typology for the water sector, specific technologies are described. Notably, most technologies/practices fit into more than one typology because they can contribute to more than one aspect of climate change adaptation. The six typologies and technologies therein are outline in the Table 7 below (Section 4.4 for detailed outline).

Table 7. Summary of existing technologies in the water sector

Typology	Technology Variations
Diversification of Water Supply	Greywater Reuse
	Rainwater Harvesting
	Stormwater Capture and reuse
	Waste water reclamation
Ground Water Recharge	Rainwater Collection from Ground Surfaces—Small Reservoirs and Micro-catchments
	Rainwater Harvesting from Roofs
	Water Reclamation and Reuse
Preparation for Extreme Weather Events	Boreholes as a Drought Intervention for Domestic Water Supply
	Improving Resilience of Protected Wells to Flooding
	Post-construction Support for Community-managed Water Systems
	Water Safety Plans
Resilience to Water Quality Degradation	Household Water Treatment and Safe Storage
	Improving Resilience of Protected Wells to Flooding
	Leakage Management, Detection and Repair in Piped Systems
	Post-construction Support for Community-managed Water Systems
	Rainwater Harvesting from Roofs
	Water Reclamation and Reuse
	Water Safety Plans
Storm Water Control and Capture	Rainwater Collection from Ground Surfaces—Small Reservoirs and Micro-catchments
	Rainwater Harvesting from Roofs
Water Conservation	Increasing the Use of Water-efficient Fixtures and Appliances
	Leakage Management, Detection and Repair in Piped Systems

4.4 Adaptation technology options and benefits in the water sector

A range of technology options for the water sector endorsed by stakeholders for their potential to reduce the sector's vulnerability to the impacts of climate change detailed below. The technology factsheet for each of these technologies is annexed (Annex 2) and contains a brief description of the technology, application potential in the country, and costs, technical aspects, and environmental impact.

4.4.1 Diversification of water supply

Diversification of the resources used for water supply can reduce vulnerability to climate change. Exploring alternatives to freshwater resources can further bolster resilience. Diversification of water supply can occur at different scales, from dam projects that may serve an entire country to interventions at the household level.

a) Water reuse

Water reuse protects the environment, results in less pollution, utilizes resources in a more sustainable manner, allows its waste and products to be recycled, and handles residual wastes in a more acceptable manner.

b) Post-construction support for community managed water systems

Post-construction support increases the success and sustainability of community managed water systems. Rural water supply interventions have historically suffered from high rates of failure. Applying a ‘demand-driven, community-managed’ model to rural water projects yields substantial improvement in the success and sustainability of rural water supplies.

c) Rainwater collection from ground water surfaces – small reservoirs and micro-catchments

The earthen bunds or embarkments are built from soil excavated from within the reservoir to increase storage capacity. A spillway or weir allows controlled overflow when storage capacity is exceeded.

d) Rainwater harvesting from roofs

Rainwater harvesting for storage is a practice in which rainwater is collected and stored for productive use. The rainwater most common storage devices for harvesting rainwater are tanks. The tanks are commonly plastic, but can also be made from concrete or stone depending on resource availability and costs. Simple tanks are commonly used for water capture and storage at the household level, while large capture ponds built into the ground are often for community initiatives.

4.4.2 Preparation for extreme events

The intensification of the global hydrological cycle is projected to increase risk of extreme wet and dry events in many areas.

a) Boreholes as a drought intervention for domestic water supply

Boreholes form the basis of conventional approaches to improving groundwater access in rural areas during drought. They are frequently appropriate for mitigating extreme symptoms of drought. Groundwater surveys and proper siting of boreholes are necessary for achieving maximum impact.

b) Water safety and security plans

Water safety plans are a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water. They enable identification of threats to water safety during all steps in the catchment, transport, treatment and distribution of drinking water. The approach can ensure that water quality is maintained in almost any context.

4.4.3 Water onservation

Conservation increases resilience to drought, prevents groundwater depletion and postpone the need for expansion of water reservoirs and treatment facilities.

a) Increasing the use of water efficient fixtures and appliances

Common water efficient appliances include clothes washing machines and popular fixtures include toilets and showerheads. They can use less water while yielding comparable performance. The appliances can be devices that use grey water from the sink for toilet flushing.

b) Leakage management, detection and repair in piped systems

Before implementing formal leak management, detection and repair programs, a water audit should be performed to quantify leakage and prioritize leak management activities. Water audits are typically conducted by monitoring water inputs, flow throughout the distribution system, and customer use during low-flow period (at night); these are used to quantify losses and identify zones with high leakage.

4.4.4 Resilience to water quality and degradation

Climate change is projected to have adverse effects on water quality. Higher temperatures, extreme precipitation events and periods of low flow exacerbate many forms of water pollution.

a) Household water treatment and safe storage

Popular treatment technologies include chemical disinfectants, coagulants, ceramic filters, biological sand filters, solar disinfection, or ultraviolet disinfection processes and both coagulant and disinfectant. These technologies improve the microbiological and, in some cases, the chemical quality of drinking water and reduce diarrheal diseases.

4.5 Criteria and process of technology prioritisation

The criteria and process of technology prioritization in the water sector is similar to the agriculture sector discussed in detail in Section 3.5 above. Similarly, MCA was used for ranking and prioritization of the listed technologies in the water sector. The criteria informing the prioritization of the technologies in the water sector included consideration of eight variables (Table 2). Each criterion was analysed and scored as described in Section 3.5 above

For each adaptation technology, stakeholders scored the benefit criteria on a scale of 0 – 100 with zero being the least benefit and 100 the highest derived from the technology for the criterion. It was difficult determining actual costs for the two cost criteria so in the end the group decided to use a scoring system of 0 – 100 with 0 being the highest cost and 100 the least cost involved in implementing and operating the technology. In the few cases where the group could not agree on a score by consensus, a majority decision was taken. Scores were entered into a scores sheet on an Excel spreadsheet (Table 9).

4.6 Results of technology prioritisation

The weighted total scores and the prioritised technologies are presented in Table 10 which shows the ordered technologies, criteria, weighted scores, weighted total scores and the ranks. The results show that the three highest ranked technologies (with ranks 1 – 3) are: 2); 1) Rainwater Collection from Ground Water Surfaces, Small Reservoirs, and Microcatchments; 2) Boreholes as a drought intervention for domestic water supply; and 3) Increasing the use of water efficient fixtures and appliances. **However, following the sensitivity analysis where**

the weighting of climate related criteria were increased to 35% with similar reasoning discussed in the agriculture sector. The technologies were re-ranked as follows: 1) Water reuse; 2) Rainwater collection from ground water surfaces; and 3) Boreholes as a drought intervention for domestic water supply.

Table 8. Actual scores for each water sector technology against the criteria

Technology	Costs		Benefits									
			Economic	**Institutional/Political**		**Social**		**Environmental**		**Climate related**		**Technological**
	Cost to set up the technology	Cost to operate the technology	Ability to reinvest	Replicability	Aligned to national development policies	Contribution to sustainable development	Social acceptability	Support ecosystem services	Protect environmental resources	Reduce vulnerability to climate change	Mitigation co-benefits	Efficiency
Water reuse	100	90	70	70	100	90	80	70	70	90	20	80
Post-construction support for community managed water systems	90	90	50	70	80	80	80	40	40	80	0	40
Rainwater collection from ground water surfaces - small reservoirs and micro-catchments	70	50	70	70	80	80	70	70	70	80	20	65
Boreholes as a drought intervention for domestic water supply	80	30	90	80	80	80	75	40	35	80	20	80
Increasing the use of water-efficient fixtures and appliances	80	30	90	70	80	70	60	70	70	60	10	80
Leakage management, detection and repair in piped systems	70	40	65	70	65	80	55	55	60	70	10	65
Household Water Treatment and Safe storage	60	30	60	55	60	60	65	35	40	70	5	65

Table 9. Relative scores for each water sector technology against the criteria

	Costs		Benefits									
			Economic	Institutional/Political		Social		Environmental		Climate related		Technological
Technologies	Cost to set up the technology	Cost to operate the technology	Ability to reinvest	Replicability	Aligned to national development policies	Contribution to sustainable development	Social acceptability	Support ecosystem services	Protect environmental resources	Reduce vulnerability to climate change	Mitigation co-benefits	Efficiency
Water reuse	0	0	50	60	100	100	100	100	100	100	100	100
Post-construction support for community managed water systems	25	0	0	60	75	67	100	14	14	67	0	0
Rain water collection from ground water surfaces - small reservoirs and micro-catchments	75	67	50	60	75	67	60	100	100	67	100	63
Boreholes as a drought intervention for domestic water supply	50	100	100	100	75	67	80	14	0	67	100	100
Increasing the use of water-efficient fixtures and appliances	50	100	100	60	75	33	20	100	100	0	50	100
Leakage management, detection and repair in piped systems	75	83	38	60	38	67	0	57	71	33	50	63
Household Water Treatment and Safe storage	100	100	25	0	25	0	40	0	14	33	25	63

Table 10. Weighted total scores and ranks of technologies in the water sector

			Benefits											
	Costs		Economic	Institutional/Political		Social		Environmental		Climate related		Technological		
Technologies	Cost to set up the technology	Cost to operate the technology	Ability to reinvest	Replicability	Aligned to national development policies	Contribution to sustainable development	Social acceptability	Support ecosystem services	Protect environmental resources	Reduce vulnerability to climate change	Mitigation co-benefits	Efficiency	Total score	Rank
Rainwater collection from ground water surfaces - small reservoirs and micro-catchments	**1125**	**670**	**750**	**120**	**225**	**335**	**300**	**600**	**900**	**1005**	**500**	**630**	**7160**	**1**
Boreholes as a drought intervention for domestic water supply	**750**	**1000**	**1500**	**200**	**225**	**335**	**400**	**84**	**0**	**1005**	**500**	**1000**	**6999**	**2**
Increasing the use of water-efficient fixtures and appliances	**750**	**1000**	**1500**	**120**	**225**	**165**	**100**	**600**	**900**	**0**	**250**	**1000**	**6610**	**3**
Water reuse	0	0	750	120	300	500	500	600	792	1500	500	500	6562	4
Leakage management, detection and repair in piped systems	1125	830	570	120	114	335	0	342	639	495	250	630	5450	5
Household Water Treatment and Safe storage	1500	1000	375	0	75	0	200	0	126	495	125	630	4526	6
Post-construction support for community managed water systems	375	0	0	120	225	335	500	84	126	1005	0	0	2770	7
Criterion weight	15	10	15	2	3	5	5	6	9	15	5	10	100	

Table 11. Sensitivity analysis for technologies in the water sector

	Costs		Benefits											
			Economic	Institutional/Political		Social		Environmental		Climate related		Technological		
Technologies	Cost to set up the technology	Cost to operate the technology	Ability to reinvest	Replicability	Aligned to national development policies	Contribution to sustainable development	Social acceptability	Support ecosystem services	Protect environmental resources	Reduce vulnerability to climate change	Mitigation co-benefits	Efficiency	Total score	Rank
Water reuse	**0**	**0**	**500**	**120**	**300**	**500**	**500**	**600**	**792**	**2500**	**1000**	**1000**	**7812**	**1**
Rainwater collection from ground water surfaces - small reservoirs and micro-catchments	**750**	**335**	**500**	**120**	**225**	**335**	**300**	**600**	**900**	**1675**	**1000**	**630**	**7370**	**2**
Boreholes as a drought intervention for domestic water supply	**500**	**500**	**1000**	**200**	**225**	**335**	**400**	**84**	**0**	**1675**	**1000**	**1000**	**6919**	**3**
Increasing the use of water-efficient fixtures and appliances	500	500	1000	120	225	165	100	600	900	0	500	1000	5610	4
Leakage management, detection and repair in piped systems	750	415	380	120	114	335	0	342	639	825	500	630	5050	5
Household Water Treatment and Safe storage	1000	500	250	0	75	0	200	0	1267	825	250	630	3856	6
Post-construction support for community managed water systems	250	0	0	120	225	335	500	84	126	1675	0	0	3315	7
Criterion weight sensitivity analysis	10	5	10	2	3	5	5	6	9	25	10	10	100	

Chapter 5 Summary and conclusions

Adaptation is an essential element of human response to climate change. The adverse impacts of climate change on the different economic and livelihood sectors are now palpable in Lesotho and are projected have severe impact on livelihoods in the long term. Therefore, it is necessary to access and adopt a diverse array of adaptation technologies and practices that are appropriate and affordable in local contexts of Lesotho. The scale of the adaptation technologies/practices should ideally range from the individual household level (e.g. adoption of climate smart agriculture practices at household level) to the community landscape scale (e.g. climate rangeland management practices on common property landscapes) to large scale national and /or private sector e.g. waste management facilities.

The national inception workshop held to launch the Technology Needs Assessment (TNA) Project in Lesotho provided a forum for deciding on which sectors to work on under adaptation. The workshop was aimed at facilitating enhanced awareness and active engagement of a broader group of stakeholders on the TNA process and addressing relevant issues relating to the TNA process such as the choice of the sectors for the TNA. The water, agriculture and infrastructure sectors were initially proposed as the sectors to be considered under adaptation. However, following discussions and through use of the multi-criteria analysis technique, the workshop participants decided on the agriculture and water resources sectors since both sectors are at the base of the country's socio-economic development. It was also suggested that infrastructure be an integral element of both the agriculture and water resources sectors.

The results of this Technology Needs Assessment (TNA) process prioritized three technologies for each of the priority sectors for adaptation i.e. The agriculture and Water Sectors. In the agriculture sector, the three highest ranked technologies following a sensitivity analysis in which the climate related criterion was given higher weighting are as follows: 1) Decentralised community run early warning systems; 2) Rainwater harvesting; and 3) Conservation Agriculture.

The identified water sector adaptation technologies are divided into five categories i.e. a) Diversification of Water Supply, b) Preparation for Extreme Events, c) Water Conservation, d) Resilience to Water Quality and Degradation and e) Improved Knowledge of Water resources and Water Demand. These technologies were drawn from a broad range of water resources management practices in the country. Finally, the three highest ranked technologies are: **1) Water reuse, 2) Rainwater collection from ground water surfaces; and 3) Boreholdes as a drought intervention for domestic water supply.**

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Annexes

Annex 1 – Fact Sheets for Selected Agriculture Sector Adaptation Technologies

1.0 Integrated Climate Change Monitoring and Early Warning System

Technology Characteristics

Introduction

This technology combines a National Climate Change Monitoring System, a Seasonal to Interannual Prediction System and a Decentralised Community-run Early Warning System to provide comprehensive, wide range and distributed information for implementation of appropriate adaptation measures against the impacts of climate variability and change across a range of spatial scales.

For countries to understand their local climate better and thus be able to develop scenarios for climate change, they must have adequate operational systematic observing networks, and access to the data available from other global and regional networks. These systems enable the integration of national early warning systems, GIS mapping of vulnerable areas, meteorological information on flooding and droughts, as well as the mapping of disease outbreaks. In this way, they provide indicators for monitoring the impacts of climate change and facilitate disaster preparedness and adaptation planning.

It is critical to provide access to information about expected climate changes which should clearly explain the uncertainty involved in estimating future impacts. Monitoring climate change, forecasting impacts and using early warning systems to disseminate data to a range of stakeholders from the national to the local level are all vital components to successful long-term adaptation planning and implementation. A climate change monitoring system integrates satellite observations, ground-based data and forecast models to monitor and forecast changes in the weather and climate.

A Seasonal to Interannual Prediction System allows for a forecast of weather conditions for a period of three to six months ahead. Seasonal forecasts are based on existing climate data; in particular, on sea surface temperatures, which are then used in ocean-atmosphere dynamic models, coupled with the synthesis of physically plausible national and international models. Modern and science-based systems facilitate seasonal forecasting. Predicting climate seasonal anomalies requires the use of complex coupled atmosphere-ocean models. Knowledge of climatic variability can lead to better decisions in water resources management and agriculture, regardless of geographical location and socio-economic conditions; the technology can therefore increase preparedness and lead to better social, economic and environmental outcomes.

An Early Warning System (EWS) is a set of coordinated procedures through which information on foreseeable hazards is collected and processed to warn of the possible occurrence of a natural phenomenon that could cause disasters. Decentralised community systems, usually operated by a network of volunteers employing simple equipment to monitor meteorological conditions and operate radio communication networks. Operators of decentralised community meteorological stations report the information to a local forecasting centre where the data is analysed and then communicated back to the community network. The demand for community-led systems is increasing due to lower operational costs and the need for local forecasting and monitoring of climate variability and potential disasters. EWS technology designed as a climate change adaptation strategy must therefore be capable of forecasting a number of climatic events that correspond to different time scales such as three to four months of advance warning of a drought and a few hours of advance warning of torrential rain, hail and floods.

The main disadvantage of an integrated climate monitoring system is the cost. Not just the capital required to purchase, install and/or operate all the necessary equipment, but also the ongoing costs of maintaining the equipment and ensuring accurate collecting of data, building and maintaining databases, making sure that data is correctly interpreted and, ultimately, ensuring that relevant information is communicated to the appropriate people in a timely fashion.

1.0 Integrated Climate Change Monitoring and Early Warning System	
Institutional and Organizational Requirements	While an integrated climate monitoring system may be managed and coordinated by the designated National Meteorological or Hydrometeorological Service (NMHS), decentralized systems involves a participatory, cross-disciplinary research approach that brings together institutions (partnerships), disciplines (such as climate science, agricultural systems science, rural sociology, and many other disciplines) and people (scientists, policy makers and direct beneficiaries) as equal partners.
Operation and maintenance	An integrated climate monitoring system is itself a network of regional and local monitoring resources, but the whole system must be managed and coordinated by the Lesotho Mel Meteorological Service (LMS) as a designated national service (NMHS). The LMS should also share climatic data readily with other relevant national and international organizations, as well as with researchers
Endorsement by Experts	The integrated technology is endorsed by national experts
Adequacy for Current Climate	It empowers stakeholders at all levels, from national to local, to plan adequately to adapt to current climate variability and future climate change.
Size of beneficiary group	The technology is beneficial countrywide and across all sectors.
Disadvantages	Disadvantages include the high cost of implementing and maintaining the systems and the requirement for highly trained and skilled personnel across many disciplines and down to the local level to collect, analyse, interpret and disseminate hydrometeorological data and information.
Capital Costs	
Costs to Implement the Technology	Costs are high and could exceed US$6,000,000.00 (Clemens et al., 2011)
	Additional cost to of maintainance and security of equipment in remote areas is high.

1.0 Integrated Climate Change Monitoring and Early Warning System	
Development Impacts, Indirect Benefits	
Reduction of vulnerability to climate change, indirect	Contributes to reduction of vulnerability to climate change by making critical weather and climate information available in a timely manner for adaptation planning.
Economic Benefits	
Employment	Creation of jobs for people in a wide range of disciplines – climate scientists, meteorologists, agriculture scientist, socio-economists, support operation and maintenance of water systems and to provide training to users/households and communities.
Investment	The investment potential of this technology in Lesotho shall, for the foreseeable future, remain the exclusive domain of government because of the limited market potential given size of the economy. That notwithstanding, the economic potential of investments in this technology package are theoretically good and will grow gradually as the role of agriculture as an economic driver grows in proportion.
Public and private expenditures	Reduce public and private expenditures on climate related disaster management
Social Benefits	
Income	Ensuring availability of weather and early warning information to communities in a timely manner would not only help reduce loss of property and livelihoods in extreme events such as floods and droughts but would also enable communities plan their agricultural and agribusiness activities in a manner that would enhance their incomes
Learning	Training elements from capacity building in operation and maintenance of systems at various levels
Health	The early warning systems in particular would enable people prepare for extreme events such as flooding and drought and reduce health risks associated with them.
Environmental benefits	
Good and reliable climate and weather information would assist in environmentally sustainable development	

<table>
<tr><th colspan="2">1.0 Integrated Climate Change Monitoring and Early Warning System</th></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Local context</td></tr>
<tr><td>Opportunities and Barriers</td><td>Scientific weather monitoring and short term forecasts (a few days) are already being undertaken in Lesotho. As “traditional indicators” of weather (e.g., bird and animal movement, the date and quantity of the first rains, the special forecasting knowledge of diviners and religious leaders, etc) become more unreliable, due largely to climate change, local communities previously relying on such indicators would embrace more and more the scientific systems. Barriers include the high cost, given that there are many competing demands for national resources and the possibility of providing information that the public cannot understand and make use of. Also, local communities that rely on “traditional indicators” for weather and seasonal forecasting may be resistant to the new technology.</td></tr>
<tr><td>Market Potential</td><td>Market potential exists in the supply of basic monitoring equipment.</td></tr>
<tr><td>Status</td><td>Lesotho already has a Meteorological Agency in charge of a wide network of weather monitoring stations throughout the country.</td></tr>
<tr><td>Timeframe</td><td>The implementation can start now.</td></tr>
<tr><td>Acceptability to local stakeholders</td><td>The technology is acceptable to local stakeholders.</td></tr>
</table>

1.1 Decentralized Community Run Early Warning System	
Technology Characteristics	
Introduction	An Early Warning System (EWS) is a set of coordinated procedures through which information on foreseeable hazards is collected and processed to warn of the possible occurrence of a natural phenomenon that could cause disasters. These systems are acquiring more importance in view of increased climate variability and the ability to implement them has become fundamental for improving capacity to adapt to climate change. The systems are either i) Centralised i.e. implemented by national government body e.g. LMS and DMA as responsible entities for implementing hazard warning and response activities; or
Institutional / Organizational Requirements	To implement a decentralised community EWS, monitoring and surveillance equipment is required. This implies handling real-time information and establishing regional and national mechanisms for exchanging technical/scientific information. Also required is the establishment of a system operating centre and communication system, as well as participatory planning of preparedness and response protocols.
Operation and maintenance	Decentralised community systems are operated by a network of volunteers employing simple equipment to monitor meteorological conditions and operate radio communication networks. They report the information to a local forecasting centre where the data is analysed and then communicated back to the community network. Three main implementation stages are critical in a decentralised community system: i) Establishing an organising committee (leaders of the community and civil society, NGOs, representatives of local authorities and the private sector); ii) Creating and analysing information: building and installing measuring instruments, carrying out forecasts; iii) Producing a participatory emergency and contingency plan; and iv) Implementing a communication system: early warnings, dissemination of prevention, mitigation and adaptation measures.
Endorsement by Experts	Empowering local communities to leverage their latent potentials and indigenous knowledge a highly commended form of participation hence highly endorsed by experts.
Adequacy for Current Climate	A decentralized community run EWS technology designed as a climate change adaptation strategy is capable of forecasting a number of climatic events that correspond to different time scales: i) Three to four months of advance warning of a drought; ii) Two to three weeks of advance warning of freezing weather conditions; or iii) A few hours of advance warning of torrential rain, hail and floods. This technology contributes to the climate change adaptation and risk reduction process by improving the capacity of communities to forecast, prepare for and respond to extreme weather events and thereby minimise damage to infrastructure and social and economic impacts, such as loss of livelihoods.
Size of beneficiary group	These would benefit all members of the community within specified catchment areas.

1.1 Decentralized Community Run Early Warning System	
Disadvantages	The majority of EWSs were established to prevent or reduce the impacts of climate-related disasters (such as floods). By comparison, the capability of these systems to forecast droughts and extreme colds has been less effective. Droughts are particularly distinguishable from other extreme weather events in that they begin slowly and gradually and are less 'obvious' at the outset. In addition, drought can last extended periods of time and affect extensive areas. Given these complexities, EWS systems should be complemented with historical data on droughts, along with available climatological, hydrological, physical, biological and socioeconomic statistics. Only by combining this data can the complex causes of droughts be better understood and different scenarios modelled with the aim of developing prognoses (such as the probable start date of the rainy season or possible variations in rainy and dry seasons) to be disseminated via appropriate communication channels.
Capital Costs	
Costs to Implement the Technology	The demand for community-led systems is increasing due to lower operational costs and the need for local forecasting and monitoring of climate variability and potential disasters. The initial implementation costs of a decentralised system comprised of ten local governments in one micro-water basin are estimated at US$ 52,000 and annual operating costs are estimated at US$ 25,000 (Clements et al., 2011).
Reduction of vulnerability to climate change, indirect	Development benefits and other co-benefits provided by this technology include: i) Introduction of hazard-related and disaster management concepts into community-level planning processes; ii) Exchange of information of a social or legal nature, in addition to climatic information, through the established communication network; iii) Facilitation of decision-making in political organisations; iv) Creation and improvement of a structure that incorporates different stakeholders involved in drawing up specific action plans
Economic Benefits	
Employment	This technology contributes to the climate change adaptation and risk reduction process by improving the capacity of communities to forecast, prepare for and respond to extreme weather events and thereby minimise damage to infrastructure and social and economic impacts, such as loss of livelihoods.
Investment	This technology enhances capacity building of communities and is thus a livelihood protection investment
Public and private expenditures	Reduce public and private expenditures on climate related disaster management
Social Benefits	
Income	These system is likely to ensuring availability of weather and early warning information to communities in a timely manner. The benefit is in helping reduce loss of property and livelihoods in extreme events such as floods and droughts. This would also enable communities plan their agricultural and agribusiness activities in a manner that would enhance their incomes.
Learning	Training elements from capacity building in operation and maintenance of systems at various levels
Health	The early warning systems in particular would enable people prepare for extreme events such as flooding and drought and reduce health risks associated with them.

1.1 Decentralized Community Run Early Warning System	
Environmental benefits	
Locally derived climate information and data is likely to be good and reliable. This would assist in environmentally sustainable development.	
Local context	
Opportunities and Barriers	The decentralised community system provides an opportunity for building awareness on climate change and disaster risk prevention approaches. It also provides opportunities for building capacity in decentralisation, participatory planning and budgeting processes whereby previously centralised roles are transferred to local governments and community stakeholders. The obstacles that could prevent the successful implementation and use of the technology are related to a number of factors including community lack of confidence in a new and unfamiliar system, problems with the dissemination of information to rural populations living in remote areas and the financial and management sustainability of the system.
Market Potential	Market potential exists in the supply of basic monitoring equipment.
Status	The Village Disaster Risk Reduction Teams (VDRRTs) of the DMA are established in Lesotho and this system would anchor on the existing network of these teams.
Timeframe	This can be implemented within a medium term framework
Acceptability to local stakeholders	VDRRTs are enjoy high acceptability in rural communities in Lesotho. However, experience shows that the teams are sustainably active under a good support system of NGOs and less so under the government operations.

1.2 Index-based Climate Insurance

Technology Characteristics

Introduction

Climate insurance against crop loss is common in developed country agriculture where farmers insure against crop loss due to extreme climatic events such as flooding or drought. Typically, payments are made on the basis of the crop loss from on-farm inspections. However, the on-farm inspections can be expensive and potentially subjective. The table below gives a summary of different kinds of agricultural climate insurance schemes.

Insurance Product	Basis	Applicability
Named Risk Climate Insurance	Insurance against loss for specific event, for specific amount, loss verified in the field	Example: hail insurance that causes a specific catastrophic loss that can immediately be identified in the field
Multiple Risk Climate Insurance	nsurance against yield loss below 50-70 per cent of expected yield due to any cause	High costs, and requires verification in the field of actual yields
Area/Yield Index Insurance	Insured against yield loss below a certain per cent across a district. Yield changes verified independently on a sample of farms across the district	Suitable for losses from drought, lower costs as not verified on each farm, but assumes same average effect across all farms in a district
Climate Weighted Index Insurance	Insurance based on certain climatic conditions being met. If met certain loss of production assumed and compensated for	Allows large number of small holdings to be aggregated in a uniform area. Low cost as no verification, but high cost of development of models, and meteorological monitoring
Normalised Difference Vegetation Index	Based on satellite monitoring of vegetation development	Mainly applicable to grazing lands
Livestock Mortality Index	Based on independent estimates of livestock mortality rates	Managed communally or through NGOs
Flood Insurance	Traditionally based on individual verification of areas flooded and damage incurred. Exploring index based systems based on satellite monitoring of area and number of days flooded versus crop losses	Requires prior registration of areas under different landuses by farmers. Risk levels vary considerably over small geographic distances

1.2 Index-based Climate Insurance	
Institutional / Organizational Requirements	The development of indexed linked climate insurance as a commercial product has generally involved the collaboration between interested insurance companies (whether public or private) and facilitated by national or multi-lateral organisations such as the World Bank or regional development banks who have subsidised the costs of development of climate insurance products. Even after a product has been developed, substantial investment needs to be made to explain the product to farmers or their representatives. One essential aspect is educating farmers to understand the product and not create false expectations about what it offers, but not reinforce the mistrust that many farmers have of these kinds of product.
Operation and maintenance	The insurance costs are reduced as no in-situ verifications are made of actual losses. This makes it viable to provide coverage to a large number of small-scale producers for whom it would be unviable to provide standard insurance. The insurance is most easily administered as part of other financial services to farmers, principally credit, and the insurance can be against not being able to pay back the credit in event of losses due to extreme climatic events. This would reduce the risk of farmers losing their land or other assets due to climatic extremes.
Endorsement by Experts	Many NGOs have also developed interest in these products. It seems clear that a private insurance company on its own is unlikely to develop climate insurance products. Usually, climate insurance is developed through some kind of public-private partnership. However, the technology has strong expert endorsement.
Adequacy for Current Climate	Index based climate insurance uses models of how climate extremes affect crop production to determine certain climate triggers that if surpassed cause substantial crop loss and would support a compensation payment. This has the advantage of being totally objective and not requiring on-site inspection.
Size of beneficiary group	The beneficiary group will start small among the emerging commercial farmers and commodity associations
Disadvantage	Index based insurance requires significant capacity for analysis of weather-related risk to design the index, good historical weather records, and extensive network of weather stations for monitoring current climate. Another disadvantage is that as payments are connected to the climate surpassing a certain trigger, if crop losses occur without passing this trigger then no payment will be made. Or conversely, if the trigger is passed, payment will be received even if no losses have occurred. This is a cost of not having any in-situ inspection. However, it runs the risk of farmers' expectations of compensation not being met, and doubting the value of the insurance.
Capital Costs	
Costs to Implement the Technology	Normally farmers would pay for the insurance, either directly or more commonly as an additional financial service associated with a loan. In some cases the costs of insurance are subsidised by the government, where it is considered strategic for the country to support buffering the impacts of climate change. In some cases countries may participate in the re-insuring of the initial insurance which also reduces the costs of the premium.

1.2 Index-based Climate Insurance	
Reduction of vulnerability to climate change, indirect	Crop losses in years of extreme climatic events can cause extreme hardship on farmers. It can force them into debt, leading them to sell their assets, even their land, and preventing them from being able to invest in the following year's production. These events are considered to be a considerable cause of why resource poor farmers are unable to accumulate sufficient goods and capital to rise out of poverty. With climate change it is expected that extreme climatic events are likely to become more frequent and thus their impacts on the livelihoods of farmers. Almost all farmers have traditional coping mechanisms for surviving periods of drought, such as selling livestock and temporary migration to sell their labour. However, these mechanisms may not be able buffer the impacts of extreme events, or droughts lasting more than one season. Therefore, it is critical to find financial mechanisms to support farmers in years of financial loss due to climatic events. Also, if such losses become more frequent then farmers will be less willing to take out credit, and lenders may be less willing to lend (or increase the costs of lending) due to the higher risks involved. If farmers do not have access to credit then this severely limits their capacity to invest in improving productivity and profitability of the agricultural livelihood.
Economic Benefits	
Employment	Creation of jobs for people in a wide range of disciplines – climate scientists, meteorologists, agriculture scientist, socio-economists, support operation and maintenance of an insurance system both in the private and public sectors of the economy.
Investment	The technology stabilizes investment in agriculture and creates opportunities for further investment in supporting business.
Public and private expenditures	Usually, climate insurance is developed through some kind of public-private partnership.
Social Benefits	
Income	Mitigating the risk from climate change will induce investments in agriculture and job creation hence income for farmers and communities.
Learning	This technology will require learning systems to make both farmers and policy makers in the public sector to understand how it works and what kind of policy support initiatives are necessary.
Health	The technology enhances the stability and nutrition aspects of food security. This will have a positive impact on health.
Environmental benefits	
Index based climate insurance uses models of how climate extremes affect crop production to determine certain climate triggers that if surpassed cause substantial crop loss and would support a compensation payment. The assurance of compensation would encourage investments in conservation measures with long term positive impacts and environmental benefits.	

1.2 Index-based Climate Insurance

Local context

Opportunities and Barriers	The World Bank has supported the design and piloting of climate insurance schemes in many countries across the world. So have other development agencies such as USAID, DFID and the regional development banks. Nevertheless, most of the initiatives have also required the support from national governments, and technical support financed by external agencies. Most farmers are not accustomed to insurance and in many cases do not have a good understanding of the nature of the product or the probabilities of it compensating for any loss. The success of such schemes offered directly to farmers hinges on considerable investments in raising farmers' awareness about financial risk management. Fortunately considerable expertise has now been developed. One of the major barriers to implementation is the need to re-insure the climate insurance provided by insurance companies. This is necessary as an extreme weather event normally covers a substantial proportion of many countries and there may be limited economic capacity to meet all the claims resulting from the event. Nevertheless, achieving re-insurance requires a solid financial model to convince these companies to assume this risk at a reasonable price. Again public participation in these schemes, whether from national or multi-lateral bodies (who would often have to cover the costs of recovery from natural disasters anyway) can reduce the costs of re-insurance or make it more acceptable to the international insurance industry.
Market Potential	There is a high potential given the thrust for fruit production and wool and mohair production in Lesotho
Status	The technology is in a conceptual stage in Lesotho
TimeFrame	This is a medium to long term type of technology timeline
Acceptability to local stakeholders	The drive making a transition from subsistence to commercial farming is creating potential for acceptability of the technology by farmers

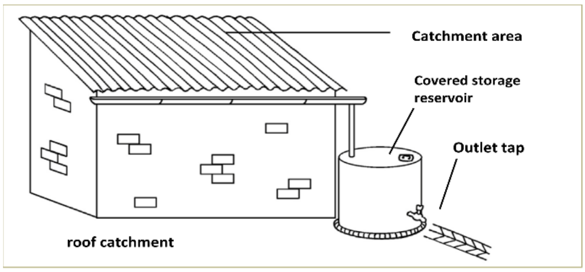
1.3 Rainwater Harvesting

Technology Characteristics

Introduction

Rainwater harvesting is a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions (Boers and Ben-Asher, 1982). Both small and large-scale structures are used for rainwater harvesting collection and storage including water pans, tanks, reservoirs and dams. The catchment area is the area where the rainfall or water runoff is initially captured and is in most cases either the roof-top of a house or building, ground surface or rock surface.

Roof-top: In the roof-top method (Fig. 6) water from rainfall is collected in vessels at the edge of the roof or channelled to a storage system via gutters and pipes.

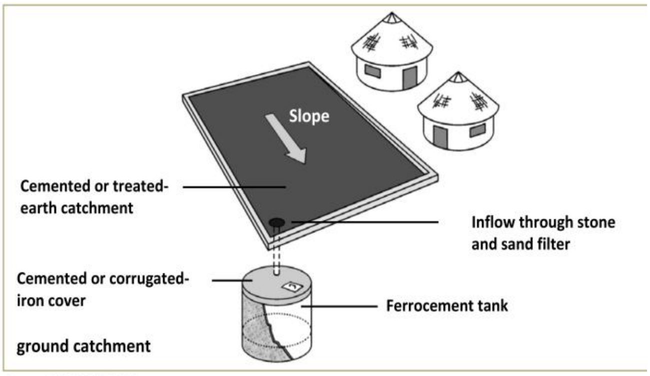


Source: UNEP IETC, 1998

Fig. 6. Schematic Diagram of a Roof water Harvesting System (UNEP-IETC, 1998).

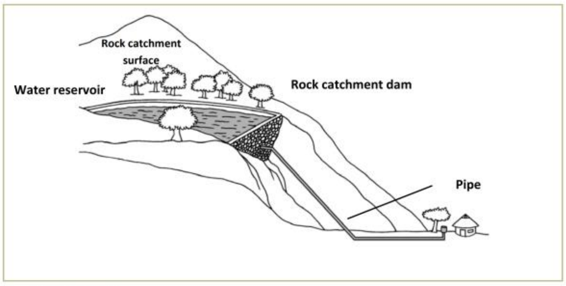
Roofs can be constructed with a range of materials including galvanised corrugated iron, or thatch. Thatch roofs can provide a low-cost alternative but can be difficult to clean and can taint the runoff. Tiled roofs, or roofs sheeted with corrugated iron are preferable, since they are the easiest to construct and give the cleanest water. Roof-top collection is suitable for household level application and can provide freshwater for domestic purposes and small-scale farming.

Ground-surface: In the ground surface method water flowing along the ground during the rains is usually diverted toward a tank below the surface (Fig. 7).



Source: UNEP IETC, 1998

Fig. 7. Schematic Diagram of a Ground-Surface Water Harvesting System (UNEP-IETC, 1998)

1.3	**Rainwater Harvesting**
	Rock-Surface: Bedrock surfaces found within rocky top slopes or exposed rock outcrops in lowlands often have natural hollows or valleys which can be turned into water reservoirs by building a dam (Fig. 8).  *Source: UNEP IETC, 1998* Fig. 8. A Schematic Diagram of a Rock Surface Water Harvesting System (UNEP-IETC, 1998)
Institutional / Organizational Requirements	Rainwater harvesting technology is simple to install and operate and does not imply any specific institutional or organisational requirements. However, government and NGOs could play a key role in providing subsidies for equipment purchases by making the technology accessible to a larger number of farmers, particularly small-scale farmers, who may have problems raising capital investment funds.
Operation and maintenance	Maintenance is required for the cleaning of the tank and inspection of the gutters, pipes and taps and typically consists of the removal of dirt, leaves and other accumulated materials. Such cleaning should take place annually before the start of the major rainfall season with regular inspections. In regions with unpredictable rainfall, more regular maintenance and cleaning will be required to ensure that the equipment is maintained in good working order. Cracks in the storage tanks can create major problems and should be repaired immediately to avoid water loss. In the case of ground and rock catchments, additional care is required to avoid damage and contamination by people and animals and to keep the catchment area free from vegetation.
Endorsement by Experts	Small reservoirs and roof water harvesting have been endorsed by experts as a means of ensuring the continuous availability of water in the dry season for rural communities, particularly for irrigated agriculture and livestock watering.
Adequacy for Current Climate	Generally, the amount of water made available through rainwater harvesting is limited and should be used prudently to alleviate water stress during critical stages of crop growth. Supplemental irrigation is a key strategy and can help increase yields by more than 100 per cent. A small investment providing between 50 and 200 mm of extra water ha^{-1} per season for supplemental irrigation, in combination with improved agronomic management, can more than double water productivity and yields in small-scale rainfed agriculture (UNEP and SEI, 2009). Thus the technology is very suitable for both current variability and future climate change. It empowers communities to adapt appropriately to seasonal and short duration rainfall conditions now and in the future.

1.3 Rainwater Harvesting

Size of beneficiary group

The technology is suitable for a wide range of beneficiary groups from urban to rural communities. However, it is best targeted to communities or clusters of communities and not few individuals.

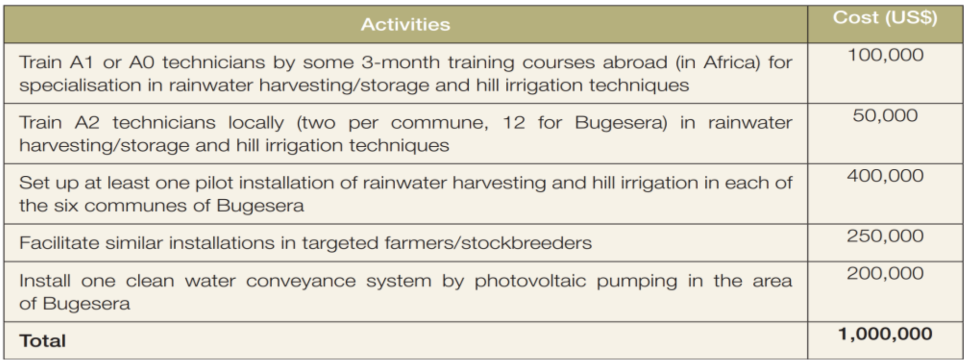
Disadvantages

The main disadvantage of rainwater harvesting technology is the limited supply and uncertainty of rainfall. Rainwater is not a reliable water source in dry periods or in time of prolonged drought. Low storage capacity will limit rainwater harvesting potential, whereas increasing storage capacity will add to construction and operating costs making the technology less economically viable. The effectiveness of storage can be limited by the evaporation that occurs between rains. In water basins with limited surplus supplies, rainwater harvesting in the upstream areas may have a damaging impact downstream and can cause serious community conflict. Also, when runoff is generated from a large area and concentrated in small storage structures, there is a potential danger of water quality degradation, through introduction of agro-chemicals and other impurities (UNEP and SEI, 2009).

Capital Costs

Costs to Implement the Technology

Rainwater harvesting technologies are simple to install and operate. Running costs are reasonably low. Construction, operation and maintenance are not labour-intensive. The following are indicative costs in a benchmark project in Burundi (Clemens et al., 2011):



Activities	Cost (US$)
Train A1 or A0 technicians by some 3-month training courses abroad (in Africa) for specialisation in rainwater harvesting/storage and hill irrigation techniques	100,000
Train A2 technicians locally (two per commune, 12 for Bugesera) in rainwater harvesting/storage and hill irrigation techniques	50,000
Set up at least one pilot installation of rainwater harvesting and hill irrigation in each of the six communes of Bugesera	400,000
Facilitate similar installations in targeted farmers/stockbreeders	250,000
Install one clean water conveyance system by photovoltaic pumping in the area of Bugesera	200,000
Total	**1,000,000**

The cost of rainwater harvesting systems will depend on the type of catchment, conveyance and storage tank materials used but in general the costs of rainwater harvesting systems is considered to be low (UNEP, 1997). The provision of the storage tank is the most costly element, and usually represents about 90 per cent of the total cost.

Construction and implementation costs of rainwater collection projects depend on many factors including the type of collection systems and the scale and location of the project. Construction costs of a small reservoir system could exceed US $50,000.00 (Clemens et al., 2011)

Reduction of vulnerability to climate change, indirect

Climate change is disrupting global rainfall patterns meaning some parts of the world are suffering from a drastic drop in precipitation leading to a fall in water levels in many reservoirs and rivers. In Sub-Saharan Africa where two-thirds of the region is desert and dryland, the need for improving water management in the agriculture sector is particularly critical. Rainwater harvesting represents an adaptation strategy for people living with high rainfall variability, both for domestic supply and to enhance crop, livestock and other forms of agriculture (UNEP and SEI, 2009).

1.3 Rainwater Harvesting	
Economic Benefits	
Employment	The technology creates employment opportunities e.g. creation of jobs to support operation and maintenance of water systems and to provide training to users/households
Investment	Rainwater harvesting and its application to achieving higher crop yields can encourage farmers to diversify their enterprises, such as increasing production, upgrading their choice of crop, purchasing larger livestock animals or investing in crop improvement inputs such as irrigation infrastructure, fertilisers and pest management (UNEP and SEI, 2009).
Public and private expenditures	Government and NGOs could play a key role in providing subsidies for equipment purchases by making the technology accessible to a larger number of farmers, particularly small-scale farmers, who may have problems raising capital investment funds.
Social Benefits	
Income	The technology creates options for stable income generation through production ventures and employment opportunities. Ensuring availability of water in communities would reduce household expenditure on more expensive potable water sources such as from water tankers and bottled water. The water can also contribute to productive and economic livelihood through irrigation and maintenance of livestock.
Learning	Rainwater harvesting technologies are simple to install and operate. Local people can be easily trained to implement such technologies, and construction materials are usually readily available. Rainwater harvesting is convenient because it provides water at the point of use and farmers have full control of their own systems.
Health	Water collected is of acceptable quality for agricultural purposes and in cases of roof water harvesting, the collection tanks can be covered and water useable for domestic purposes. Contributes to water availability and eliminates dependence of communities on unimproved water sources. Systems also used for irrigation, for example, could result in improved nutritional status of beneficiary communities. These will result in improved health for households including women and children.
Environmental benefits	
Use of rainwater harvesting technology promotes self-sufficiency and with minimal environmental impact. Environmental benefits include increasing soil moisture levels and increasing the groundwater table via artificial recharge especially for unlined reservoirs as stored water will infiltrate permeable soils during storage and eventually reach the groundwater table.	
Local context	

1.3 Rainwater Harvesting	
Opportunities and Barriers	Low and variable productivity in rainfed agricultural areas is the major cause of poverty of 70 per cent of the world's poor (UNEP and SEI, 2009). Using rainwater harvesting technology, therefore, offers a real opportunity to increase productivity in regions with low and irregular rainfall. In those regions, development and use of rainwater harvesting can provide a first entry point for success of development programmes from households, community and farm levels. The cost of rainwater storage systems is often cited as a potential obstacle to wider dissemination of this technology (Gould, 1992). For poorer households some form of financing mechanism, preferable accompanied by a subsidy, will be the only way of acquiring a rainwater harvesting system. A lack of national policy towards rainwater harvesting could also present an obstacle to widespread implementation, access to funding and technical assistance. Communally-owned systems can suffer from lack of protection, care and maintenance (Hatibu and Mahoo, 1999).
Market Potential	The technology is relevant and, though a bit expensive has market potential in the arid and semi-arid especially the southern lowlands and Senqu River valley. The market potential is good for prefabricated plastic tanks for roof water harvesting. There is also a great potential for local artisans with knowledge and skills to construct collection reservoirs using local material.
Status	Aspects of this technology, small reservoirs and check dams are already being used in various communities in Lesotho, is promoted by the Department of Soil and Water Conservation and NGOs. Thus there is a strong footing in Lesotho especially roof water harvesting being promoted by the Department of Soil Conservation. In addition, there is experience with construction of earth dams. The latter, however, are endangered by siltation. Their numbers are currently inadequate and many of the existing ones are poorly maintained due to lack of resources.
Timeframe	This technology can be implemented in both the short- and medium term. The implementation can start now to assist communities in adapting to climate variability now while preparing for adaptation to climate change impacts in the future.
Acceptability to local stakeholders	There is a high level of acceptability both in the rural and urban areas

1.4 Conservation Agriculture

Technology Characteristics

Introduction	Conservation agriculture (CA) is generally defined as a set of management practices that minimize soil disturbance, incorporate legumes through rotations or intercropping, and maintain crop residues on the soil surface. These practices are promoted in order to reduce erosion, improve soil quality through the gradual build-up of soil carbon and in the long term, improve soil fertility and water infiltration. Other benefits of conservation agriculture can be decreased labor requirements, increased yields, earlier planting and greater drought tolerance due to improvements in soil physical properties.
Institutional Requirements	In Lesotho farmers are supported by the Ministry of Agriculture and Food Security, NGOs, and Development Partners like the FAO to access technologies for CA. Private and public sector equipment suppliers also have a role in responding to demands from different types of farmers for adapted tools and equipment.
Operation and maintenance	The cost of equipment for CA depends on whether the land is tilled with motorised traction, animal-draught or manpower. The most important cost for larger producers will be machinery and fuel. However, higher herbicide applications could offset these savings, especially in the initial adoption stages. On smaller-sized farms, savings in labour costs could be substantial. Studies show that CA practices reduce labour inputs by around 50 per cent compared to traditional systems (Ehui et al, 1990). However, financial incentives and subsidies are required to assist farmers to adopt this practice.
Endorsement by Experts	CA practices have been endorsed by experts as a means of ensuring the conservation of soil water, reduction in soil erosion and in the long term reduction in weed infestation and consequently reduced environmental impact of herbicides.
Adequacy for Current Climate	Unpredictability of rainfall and an increase in the mean temperature may affect soil moisture levels leading to damages to and failures in crop yields. CA practices reduce risk from drought by reducing soil erosion, enhancing moisture retention and minimising soil impaction. In combination, these factors improve resilience to climatic effects of drought and floods (Smith, 2005). Improved soil nutrient recycling may also help combat crop pests and diseases (Holland, 2004).
Size of beneficiary group	CA technology is available for both smallscale farmers using manual to ox-drawn implements and large semi /commercial operations based on tractor mounted technologies
Disadvantages	Conservation tillage may require the application of herbicides in the case of heavy weed infestation, particularly in the transition phase, until the new balance of weed populations is established. Initial investment of time and money along with purchases of equipment and herbicides will be necessary for establishing the system. Higher levels of surface residue may result in higher plant disease and pest infestations, if not managed properly. There is a strong relationship between this technology and appropriate soil characteristics. For small scale and resource poor farmers, the labor intensiveness of CA is a serious disincentive.

Capital Costs

1.4 Conservation Agriculture	
Costs of Implementing Technology	The capital of cost of equipment i.e. ox-drawn no-till and /or tractor mounted planters are currently being imported at high cost close to US$1500 for ox-drawn NT planters to US$5000.00 for tractor mounted NT planters. However, there is a possibility of renting services for tractor technologies.
Reduction of vulnerability to climate change, indirect	Unpredictability of rainfall and an increase in the mean temperature may affect soil moisture levels leading to damages to and failures in crop yields. CA practices reduce risk from drought by reducing soil erosion, enhancing moisture retention and minimising soil impaction. In combination, these factors improve resilience to climatic effects of drought and floods (Smith, 2005).
Economic Benefits	
Employment	The technology creates employment opportunities e.g. creation of jobs to support planting and digging of planting basins at the manual scale and for weeding.
Investment	There is potential for investment in manufacturing of CA equipment locally
Public and private expenditures	Government and NGOs play a key role in providing subsidies for planting CA operations and equipment purchases to make the technology accessible to a larger number of farmers, particularly small-scale farmers, who may have problems raising capital investment funds.
Social Benefits	
Income	CA systems also benefit farmers by reducing fuel consumption because reducing the number of times the farmer travels over the field, farmers make significant savings in fuel and labour. Labour inputs for land preparation and weeding are also reduced once the system becomes established. In turn, this can increase time available for additional farm work or off-farm activities for livelihood diversification.
Learning	Farmers need extensive training to implement conservation tillage. This includes knowledge of crop rotation; analysing soil conditions; monitoring soil temperature and moisture; adjusting nutrient and weed management approaches; and selecting appropriate equipment. Studies have shown that the main limitation to the spread of no-tillage technology has been a lack of specific site knowledge about weed control. Information on common weeds, herbicide products (including details of chemical and toxicological characteristics) and application technologies are prerequisite for adoption of CA (Derpsch, 2001).
Health	Stabilizing food production under limited rainfall conditions improves food security and nutrition and consequently has positive health impacts.
Environmental benefits	
Conservation tillage benefits farming by minimising erosion, increasing soil fertility and improving yield. Ploughing loosens and aerates the soil which can facilitate some deeper penetration of roots. Tillage is believed to help in the growth of microorganisms present in the soil and helps in the mix the residue from the harvest, organic matter and nutrients evenly in the soil. Also once the system is established, requirement for herbicides and fertilisers can be reduced.	

1.4 Conservation Agriculture

Local context

Opportunities and Barriers	In the Americas, the uptake of the technology was greatly facilitated by exchange of information through farmers associations (World Bank, 2000), provision of publications with adequate, practical information on technology implementation and studies showing positive economic returns (Derpsch, 2001). A lack of locally-appropriate knowledge and/or poor research and development for CA technology presents one of the main barriers to uptake (Derpsch, 2001). Likewise, where there is no local production or availability of equipment and other inputs, such as herbicides, then costs will rise significantly and may present a barrier to implementation. Ecological barriers to no-tillage production systems include low precipitation with low biomass production, short growing seasons and soils at risk of water logging. Socio-economic constraining factors include: strong demand for crop residues as forage for livestock, uncertain land use rights, poorly developed infrastructure (market, credit, extension service)
Market Potential	The technology is relevant and, though a bit expensive has market potential in Lesotho both amongst smallholder farmers using manual and ox-drawn planters. The market potential is good for prefabricating the NT implements locally.
Status	Aspects of this technology, manual and mechanized, are already being used in various communities in Lesotho, is promoted by the Department of the Ministry of Agriculture and Food Security, NGOs and FAO.
Timeframe	This technology can be implemented in both the short- and medium term. The implementation can start now to assist farmers to secure the required mechanization equipment and know.
Acceptability to local stakeholders	The CA technology has a growing level of acceptability among smallholder farmers in Lesotho.

1.5 Technology: Integrated Soil Nutrient Management (ISNM)

Technology characteristics	
Introduction	Also referred to as integrated soil fertility management, the technology aims making efficient use of both synthetic and natural plant nutrient sources to enhance soil fertility towards improving and preserving soil productivity. The success of INM relies on the appropriate application and conservation of nutrients and transfer of knowledge to farmers. The technology enables the adaptation of plant nutrient and soil fertility management within a farming system to site specific characteristics; an important ingredient for climate change adaptation. Integrated soil fertility management in Lesotho, has been widely promoted. There is availability of capacity for effective transfer of the technology to farmers. However, the use of the technology is low compared to use of single nutrient sources.
Institutional and organizational requirements	The technology requires a well-resourced research and extension organization for its effective promotion and use. In additional there is the need for appropriate extension approaches and methodologies that provides opportunity for farmer experimentation and adoption of technology.
Operation and maintenance	The technology can be promoted using existing research, extension and farmer linkages for technology dissemination. This, however, needs to be supported by effective capacity building at various levels to support operations at farmer level.
Endorsement by experts	The technology has been endorsed as appropriate for effective management of soil resources for increased and sustainable productivity a necessity for climate change adaptation.
Adequacy for current climate	ISNM is relevant for addressing current climate change effects at farmer level. Its effectiveness will, however, be enhanced with combination with other related technologies.
Size of Beneficiary Groups	The technology has the potential of increasing the number of farmers achieving improved yields from their farms.
Disadvantages	A major disadvantage of the technology is the inadequacy of available organic nutrient sources.
Capital Costs	
Cost to implement adaptation options	The technology will contribute to cost associated with use of soil nutrients on farmers' field. It will, however, require some level of investment for packaging aspects of the technology, awareness creation, training of extensionists and farmers; and demonstrations. It will require about US$500,000 to be effectively disseminated and adopted
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Contributes to reduction of vulnerability to climate change through improvements in soil resources and increases in productivity
Economic Benefits	
Employment	The technology can contribute to generation of employment at the community level sales of transformed organic sources e.g. compost
Investment	Requires low investment in tools and equipment; and training of farmers for transforming organic sources into easily usable forms.
Public and private expenditures	Reduce public and private expenditures in terms of expenditure on the use of inorganic soil nutrients.

1.5 Technology: Integrated Soil Nutrient Management (ISNM)

Social Benefits	
Income	Could provide a source of extra income for individuals and groups from sales of transformed organic materials into organic soil nutrients e.g. compost
Learning	Creates opportunity for increased group and individual learning at group and community level
Health	The technology could provide opportunity for reducing health risks within communities from improved sanitation achieved from processing of waste.
Environmental benefits	
Integrated Soil Nutrient Management will contribute to reduction in the use of inorganic fertilizers hence reduce dangers of water pollution from poor handling and over use of chemical fertilizer.	
Local context	
Opportunities and Barriers	The major opportunity for rolling out technology lies in the fact that farmers are already using one form of soil nutrient or the other. Additionally, most farmers keep one type of livestock or the other as part of farming activities. The major barrier has is the limited integration of crops and animal production systems at the farmer level
Market Potential	The technology could create a market for organic soil nutrients
Status	The use of the technology is low across the country
Timeframe	The implementation can start now.
Acceptability to local stakeholders	The technology is acceptable to local stakeholders.

1.6 Crop Diversification and New Varieties

Technology Characteristics

Introduction	The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. There are thousands of existing varieties of all of the important crops, with wide variation in their abilities to adapt to climatic conditions. Agricultural researchers and extension agents can help farmers identify new varieties that may be better adapted to changing climatic conditions, and facilitate farmers to compare these new varieties with those they already produce. In some cases farmers may participate in crossing select seeds from plant varieties that demonstrate the qualities they seek to propagate to develop new varieties with the characteristics they desire. The introduction of new crop species to diversify the crop production systems needs to take into account the following inter-related categories: a) Availability and quality of resources including irrigation, rainfall and soil fertility; b) Access to technologies such as seed, fertiliser, water, marketing, storage and processing; c) Household related factors covering food and fodder self-sufficiency requirement as well as investment capacity; d) Price and market related factors including output and input prices as well as trade policies and other economic policies that affect these prices either directly or indirectly; e) Institutional and infrastructure related factors covering farm size and tenancy arrangements, research, extension and marketing systems and government regulatory policies.
Institutional and organizational requirements	In order to support farmer innovation, communities have to be linked to research programmes and should have access to research products. These links might be direct or through intermediary organisations such as NGOs and development organisations. In all cases, these links have to be made explicit and institutionalised. Institutional recommendations include establishing farmers' committees in order to synchronise diversification on neighbouring farms or plots that share common ecosystems. The committee exercises some authority by establishing the most appropriate crop portfolio and can provide a body that supports local farmers to access financing and technical support. Production can also be coordinated in relation to market demand, either staggering to provide a stable supply or coinciding to make a bulk sale. Government policy supporting diversification is key to facilitating access to inputs and technical skills and building national markets and developing links to external markets.
Operation and maintenance	A rigorous security assessment and compilation of an inventory of varieties by crop, including varieties currently used by farmers, as well as new varieties not yet available to farmers for testing is prerequisite. This entails an overview of the strengths and weaknesses of current agricultural and seed systems and an in-depth understanding of the root causes of any current and potential stresses. Thus, a decision to introduce new varieties must be based on evidence that new varieties offer promising opportunities, and, equally, that their introduction will not expose farmers further to increased risk. It is important to monitor and evaluate (with farmer participation) the performance of new varieties, report results and recommend next steps and changes to improve processes. It is also important to provide detailed information on yields and production conditions. In making decisions about diversification, farmers need to consider whether income generated by new farm enterprises will be greater than the existing activities, with similar or less risk. While growing new crops or raising animals may be technically possible, these may not be suitable for many farmers in terms of their land, labour and capital resources. Moreover, markets for the products may be lacking. Therefore, preliminary feasibility and market studies are recommended before crop diversification selection is implemented.

1.6 Crop Diversification and New Varieties	
Endorsement by Experts	Experts at the National University of Lesotho has endorsed the technology and released new sorghum varieties e.g. Thaha-Khube and NUL 2000.
Adequacy for Current Climate	The climate risk and vulnerability assessments revealed the hazards profile, dominant livelihood strategies, dominant land use options and the sensitivity of the livelihood systems to past and future climate change scenarios. Drought was ranked as the most important hazard and, crop failure, livestock deaths and loss of income were identified as the most important drought related risks in Lesotho. Future climate change scenarios for Lesotho showed rising temperatures and possible modification of the rainfall pattern bordering on drier conditions in the future. Downscaled climate change scenarios for the Lesotho suggested that climate change could also bring some opportunities (heavy rainfall events) that need to be captured by project beneficiaries. The process of farmer experimentation and the subsequent introduction of adapted and accepted varieties can potentially strengthen farmers' cropping systems by increasing yields, improving drought resilience, boosting resistance to pests and diseases and also by capturing new market opportunities. To make the products of the research process more relevant to the needs of smallholder farmers, research organisations are increasingly engaged in participatory research in recognition of its potential contribution to marginal areas with low agricultural potential. There is a need to identify crops and varieties that are suited to a multitude of environments and farmer preferences. Participatory approaches increase the validity, accuracy and particularly the efficiency of the research process and its outputs. Researchers are better informed and can better inform about the traits that should be incorporated in improved varieties. Participatory processes also enhance farmers' capacity to seek information, strengthen social organisation, and experiment with different crop varieties and management practices.
Size of beneficiary group	The beneficiary groups for the technology are first and foremost smallholder and commercial farmers in Lesotho because they are directly impacted by climate change. However, both academia, research institutions and policy makers will benefit from the technology.
Disadvantages	Farmer experimentation using only native varieties can limit the range of benefits and responses that may be found amongst the materials being tested, although local adaptation and acceptance are ensured. At the same time, problems can arise with the introduction of exotic species (from other origin centres) that after being introduced turn into pests or agricultural weeds (Ojasti, 2001; Hall, 2003). A limitation of crop diversification is that it may be difficult for farmers to achieve a high yield in terms of tons per hectare given that they have a greater range of crops to manage. In terms of commercial farming, access to national and international markets may be limited by a range of factors including government policy including subsidies, the price and supply of inputs, infrastructure for storage and transportation, amongst others. Farmers also face risk from poor economic returns if crops are not selected based on a market assessment. For example, drought tolerant crop varieties may fetch a low market price if there is not sufficient demand.

1.6 Crop Diversification and New Varieties	
Capital Costs	
Costs of Implementing the Technology	Costs of farmer experimentation are generally low, but results may only have local applicability. Capital investment will relate to the purchase of new seed varieties and labour time. Where farmers are implementing a project initiated by an external agency, capital costs for training, technical experts and field staff, on farm trial equipment (an experimental plot may be established), and site visits may also be required. Elsewhere a project reportedly estimated total costs of a five-year project involving around 1,000 farmers came to around $300,000 (Smale et al, 2003). Financial requirements of diversification revolve around the costs involved in researching the species to be planted and training in the management of diversified systems. Preliminary feasibility and market research need also to be considered in the financial requirements. Infrastructure (such as transport and storage) and marketing costs should also be considered.
Reduction of vulnerability to climate change, indirect	Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change. These potential stresses include water and heat stress, and the emergence of new pests. Varieties that are developed to resist these conditions will help to ensure that agricultural production can continue and even improve despite uncertainties about future impacts of climate change. The aim of crop diversification is to increase crop portfolio so that farmers are not dependent on a single crop to generate their income. When farmers only cultivate one crop type they are exposed to high risks in the event of unforeseen climate events that could severely impact agricultural production, such as emergence of pests and the sudden onset of frost or drought. With a diversified plot, the farmer increases his/her chances of dealing with the uncertainty and/or the changes created by climate change. This is because crops will respond to climate scenarios in different ways. Whereas the cold may affect one crop negatively, production in an alternative crop may increase.
Economic Benefits	
Employment	High employment opportunities from scientists, technicians and participating farmers and associated labor support. The development, testing, production and multiplication phases of the technology provide potential job opportunities.
Investment	There is great investment opportunities for private sector in partnership with academia and research institutions in the multiplication and marketing of new varieties.
Public and private expenditures	The success of the technology depends on public and private sector partnerships to support the required research.

1.6 Crop Diversification and New Varieties

Social Benefits

Income	Introducing a greater range of varieties leads to diversification of agricultural production which can increase natural biodiversity, strengthening the ability of the agro-ecosystem to respond to these stresses, reducing the risk of total crop failure and also providing producers with alternative means of generating income.
Learning	Farmer-managed demonstrations are an effective way of trying adaptation measures because Lesotho farmers have been exposed to a range of strategies within the crop sector, and also some outside crops. Thus, farmer managed demonstrations are the best way to do this, since it will make it possible to answer important evaluation questions, on: what works, why and under what circumstances. Such information will be policy relevant for up-scaling promising adaptation strategies. In making decisions about diversification, farmers need to consider whether income generated by new farm enterprises will be greater than the existing activities, with similar or less risk. While growing new crops or raising animals may be technically possible, these may not be suitable for many farmers in terms of their land, labour and capital resources. Moreover, markets for the products may be lacking. Therefore, preliminary feasibility and market studies are recommended before crop diversification selection is implemented.
Health	Varieties with improved nutritional content can provide benefits for animals and humans alike, reducing vulnerability to illness and improving overall health.

Environmental benefits

Crop diversification provides better conditions for food security and enables farmers to grow surplus products for sale at market and thus obtain increased income to meet other needs related to household well-being. Crop diversification can enable farmers to gain access to national and international markets with new products, food and medicinal plants. Diversifying from the monoculture of traditional staples can have important nutritional benefits for farmers in developing countries and can support a country to becoming more self-reliant in terms of food production. Diversification can also manage price risk, on the assumption that not all products will suffer low market prices at the same time. Compared to producing monocultures, management techniques for diversified crops generally consist of more sustainable natural resource practices.

Local context

1.6	**Crop Diversification and New Varieties**
Opportunities and Barriers	Opportunities for new and improved crop varieties arise where attractive native species can be developed for sale on national and international markets. By implementing market development strategies and integrating various actors across and within the input-supply, production, sale/storage, and marketing stages of the value chain the production, profitability and competitiveness of crops can be increased. Opportunities may also arise for innovative partnerships between producers, research institutes and the private sector. The main barrier to introducing new and improved crop varieties through farmer experimentation is the misconception that local species have low productivity. In the same vein, several communities in developing countries have lost ancient knowledge about resistant species. The main barrier to diversification is market demand which can lead farmers to produce fewer crops or monocultures and to rely on chemical inputs. In turn, this can increase vulnerability of both the agricultural system itself to external factors such as climate change, and also the farmer to price fluctuations.
Market Potential	Crop diversification provides better conditions for food security and enables farmers to grow surplus products for sale at market and thus obtain increased income to meet other needs related to household well-being. Crop diversification can enable farmers to gain access to national and international markets with new products, food and medicinal plants. Diversifying from the monoculture of traditional staples can have important nutritional benefits for farmers in developing countries and can support a country to becoming more self-reliant in terms of food production. Diversification can also manage price risk, on the assumption that not all products will suffer low market prices at the same time. Compared to producing monocultures, management techniques for diversified crops generally consist of more sustainable natural resource practices.
Status	The National University of Lesotho has developed and released two sorghum varieties (NUL 2000 and Thaha Khube) demonstrating capacity despite limited resources for production of new varieties.
Timeframe	The technology can start with immediate effect stretching to a medium term
Acceptability to local stakeholders	The technology is acceptable to stakeholders because the adoption of new hybrid varieties from South Africa is popular among farmers.

1.7 Biotechnology for Climate Change Adaptation of Crops

Technology Characteristics

Introduction	Breeding for improved performance under environmental stresses involves activities which accumulate favourable alleles (different forms of a gene) which contribute to stress tolerance. Biotechnological contributions to crop adaptation to climate change do not only, or even mainly, concern the placement into the crop of one or more genes from an organism with which the crop could not normally breed (i.e. genetically modified crops. Phenotyping (measurement of the response of a plant line in a given environment) is still a vital part of the selection process but when a genetic region shown to be conferring an adaptive advantage has been identified, it can be transferred (even across species barriers) much more rapidly and efficiently than has been possible up to now. Superior genes or alleles can often be found within other lines or races of the same crop and their efficient accumulation can be greatly speeded by molecular breeding where the presence of desirable genes or alleles can be directly and immediately identified, even in seeds or very young plants not exposed to the stress in question. More complex are marker-assisted backcrossing (MAB) and marker-assisted recurrent selection (MARS) techniques, allowing exactly identified pieces of DNA (individual alleles, genes or qualitative trait loci (QTLs) to be included in the desired plant line while minimising the transfer of other, less desirable, genes. Whole genome sequences are now available for soybean, maize, rice, sorghum and recently potato and high throughput 'next-generation sequencing' means that this process is rapidly accelerating, allowing the sequencing of large and complex genomes of crops such as wheat and barley. Desirable genetic loci identified in one genome can be quickly searched for in others.
Institutional / Organizational Requirements	The research and development aspect of the technology requires facilities hitherto limited in Lesotho. In addition, the capacity for research at individual, institutional and systemic is limited. However, gradual progress is being made at the National University of Lesotho regarding biotechnology. The Government of Lesotho needs to explore policy and regulation or legislation regarding biotechnology products and technologies.
Operation and maintenance	Many of the biotechnology responses to climate change are public sector developments intended for free or 'at cost' dissemination and are aimed at subsistence farmers with very limited ability to pay for improved inputs, particularly in the marginal environments likely to be first affected by climate change. However, the reality of the global seed distribution system make it likely that the commercial sector will be the most efficient disseminator of seed and the guardian of their purity, provided they are given some proprietary rights. Prices will then be set based on the average advantages to farmers, as in other sectors of the marketplace.
Endorsement by Experts	The technology is supported by scientific evidence regarding its environmental human health implications. However, in Lesotho the debate on the technology is largely avoided and the opinion is driven by myth.
Adequacy for Current Climate	The technology provides the means to address the climate change stressors directly and faster than the conventional plant breeding approaches. Biotechnological tools focus on providing the ability to directly detect and transfer genes of interest from other plant lines or organisms into the crop of interest without the continuing need to use the appearance or stress response of the plant (its phenotype) as a proxy for the presence of that gene.

1.7 Biotechnology for Climate Change Adaptation of Crops	
Size of beneficiary group	This technology can potentially benefit all farmers in Lesotho. In particular the burden borne by women in the tedious manual weeding operations can be alleviated by the technology. In addition, the youth reluctance to invest themselves in agriculture has potential solutions in biotechnology.
Disadvantages	Drought and flooding are unpredictable. Ensuring that the developed plants perform well in a wide range of environmental conditions is a challenge that will require even deeper understanding of the molecular basis of responses to stress. As with other areas of modern technology, molecular breeding is becoming more and more complex and inaccessible as a science for those of modest means. The financial investment needed for efficient molecular breeding is high and companies are recouping their investment through higher seed prices and selling their material only as hybrids, effectively preventing replanting any of the seeds produced. On one hand this ensures quality control in seed purity, on the other hand it creates low autonomy on the part of the farmer. Concerns over loss of crop biodiverisity have had a mixed history. to support the investment marginalising niche market varieties and land races.
Capital Costs	
Costs to Implement the Technology	Farmer cost experiences are diverse with existing bioengineered crops globally depending on the regulatory systems in place. Where private seed companies have been able to monopolise the market they have capitalised it with either famer agreements forbidding seed saving and imposing a technology fee in addition to the increased seed cost. Where this was impractical, the seed sector forced a monopoly through the production of only hybrid seeds. Prices began at six to ten times that of non-biotech seed but gradually declined to three to four times because of court requirements and increasing competition. However, even in countries where seed prices were very high, the average balance of financial benefit still rested with the farmer. After a brief period of adaptation around 60 to 80 per cent of the financial benefit of the seed tends to go the farmer and about 10 per cent to the technology developer, with the balance going to the supply chain.

1.7 Biotechnology for Climate Change Adaptation of Crops

Reduction of vulnerability to climate change, indirect

Genes that confer a measure of abiotic stress tolerance can be obtained from germbank collections, wild relatives of the crop, or from other organisms known to perform well under water deficit/excess or high salinity or temperatures. Much of the initial work has been with the plant genetics ‘guinea-pig’ Arabidopsis, however, benefits for field crops are rapidly emerging. For example the HRD gene in transgenic rice has improved water use efficiency and the ratio of biomass produced to the amount of water used, through enhanced photosynthesis and reduced transpiration (Karaba et al, 2007). Correlation of drought tolerance with root architecture (spread, depth and volume) has been examined in cowpea (South Africa), rice (India) and beans (Central and South America). The table below outlines salient trades for maize.

Product	Trade	Function	Reference
Drought tolerant maize	Expression of glutamate dehydrogenase (gdhA) gene from E.coli.	Germination and grain biomass production under drought increased	Lightfoot et al., 2007; Castiglioni et al., 2008.
	Enhanced expression of phosphatidylinositol-specific phospholipase by ZmNF-YB2 reducing stomatal conductance and so leaf temperature and water loss	Grain yield increases through reduced wilting and maintenance of photosynthesis under drought	Nelson et al, 2007

Economic Benefits

Employment

The technology has potential to generate employment from the scientific to the regulatory domains. In addition, the improvements in production and productivity will significantly increase employment at the farm level.

Investment

Research institutions and academia can do the initial research and development but it will require private investment to take the process forward

Public and private expenditures

Public private partnerships are critical for development of the technology

Social Benefits

Income

There are rather few publications on the economic impacts of biotechnology products on climate change adaptation. Alpuerto et al (2009) undertook an analysis of salinity and phosphorous tolerance in rice where the cumulative benefit to Bangladeshi farmers using marker assisted breeding rather than conventional breeding are forecast to be US$ 800 million for salinity tolerance and US$ 450 million for Phosphorus deficiency if conventional breeding takes 5 years longer than MAB, which is a conservative estimate. The medium term impact of the work described here and the many other products which are slightly less advanced but are in the pipeline is expected to be dramatic.

1.7 Biotechnology for Climate Change Adaptation of Crops

Learning	The knowledge requirements of biotechnology solutions for farmers or extension service providers are relatively low. However, an enabling environment is necessary for benefit maximisation and can sometimes be generated by it. Given the seed price implications, it is important the seed industry and extension services give farmers an accurate picture of the extent to which such crops can accommodate adverse environmental conditions and what growth and yield can be expected in local environments. The limited access of public and developing country breeding programmes to these technologies is being addressed by the Generation Challenge Programme's molecular breeding platform. This is a brave attempt to put these high-tech tools in the hands of small-scale breeders.
Health	Research, information and knowledge based on science based evidence is required to counter provide the health implications of the technology especially the genetically modified aspects.

Environmental benefits

Biotechnology solutions can be delivered to farmers to mitigate the harmful effects of climate change with potential for maintaining food and fibre production in a degrading environment and for expanding the farmable area into currently marginal environments. This is not to imply that environmental remediation is unnecessary but it helps to provide a buffer on its urgency.

Local context

Opportunities and Barriers	These yield stabilising or enhancing technologies are likely to be taken up very quickly by farmers, most particularly where heat/drought/salinity is clearly moving against them over a series of seasons. Seed companies will be slow to exploit the opportunities offered though it is likely that many of the best parental lines will emerge from public sector programmes. The global crop breeding community has found it more difficult than expected to use the outputs of molecular breeding research in its various forms for the rapid development of improved cops for poorer farmers. Even within crop species, genome structure and gene orders have proved to be more variable than expected. The prevalence of polygenic traits with strong genetics/environment interactions have been more marked than was foreseen, making successful expression of the valued trait after intra or inter-specific transfer more elusive than had been hoped. This is slowing (and deepening) research by all organisations (including commercial companies) in this area. Molecular breeding is not proving to be either faster or cheaper than conventional breeding, though its worth has already been demonstrated for simple traits. The generally polygenic nature of the traits necessary for the amelioration of climate change-induced shifts in the environment, makes this more difficult still. However, unlike conventional breeding, the knowledge gained with molecular breeding is incremental and will enable much more effective, productive, targeted and rapid crop development over time. Trait development is expensive and high quality seed lines are costly to maintain. As with other sections of the seed sector, effective variety/hybrid development and dissemination will depend on the value capture mechanisms available to the players in the seed chain.

1.7 Biotechnology for Climate Change Adaptation of Crops	
Market Potential	Properly designed, there is no reason why these mechanisms should delay the delivery of significant benefits to farmers. In the specific area of GMOs we are likely to see continued extremely high costs of regulation, significantly delaying plant provision and significantly increasing costs to farmers and pushing ownerships rights strongly into the hands of larger, often multi-national, companies. It is probably true that this regulatory burden has led to most genetically modified crop dissemination in the developing world starting in the informal sector and products only receiving regulatory approval in retrospect. This is not desirable but seems likely to continue and expand while current regulatory regimes are in place.
Status	In Lesotho there are no established policy and /or regulations.
Timeframe	Medium to long term developments
Acceptability to local stakeholders	Information and capacity building required to overcome the initial myths about the technology. However, acceptability will be high.

1.8 Seed and Grain Storage

Technology Characteristics	
Introduction	Seed security is key to the attainment of household food security among resource poor farmers in developing countries (Wambugu et al, 2009). Good storage helps ensure household and community food security until the next harvest and commodities for sale can be held back so that farmers can avoid being forced to sell at low prices during the drop in demand that often follows a harvest. While considerable losses can occur in the field, both before and during harvest, the greatest losses usually occur during storage. Therefore, the basic objective of good storage is to create environmental conditions that protect the product and maintain its quality and its quantity, thus reducing product loss and financial loss. There are two reasons for food storage: domestic security and maintaining value prior to sale.
Institutional / Organizational Requirements	Health and safety regulations and quality control guidelines should be elaborated by the relevant national authority. Standardised training and inspections may also be undertaken by the Ministry of Agriculture, Food Security and Nutrition.
Operation and maintenance	Farmers may not accept improvements which incur costs when storing primarily for home consumption because an improvement in the quality of a food produced for home consumption does not achieve a higher monetary value for the farmer.
Endorsement by Experts	The technology is endorsed by experts because of the significance of postharvest losses
Adequacy for Current Climate	The establishment of safe, long-term storage facilities ensures that grain supplies are available during times of drought. It is important to be able to store food after harvest so as not to be compelled to sell at low prices. Appropriate storing techniques can prolong the life of foodstuffs, and/or protect the quality, thereby preserving stocks year-round.
Size of beneficiary group	The technology is relevant to both smallscale farmers and commercial producers
Disadvantages	The cleaning and drying of grain for storage are essential measures. However, difficulties in achieving the desired freedom from excess moisture and foreign matter are frequently encountered. Failure to adequately clean and dry grain can lead to pest infestations. Over-drying of grains can also negatively impact seed quality. Losses of seeds from insects, rodents, birds and moisture uptake can be high in traditional bulk storage systems. Controlling or preventing pest infestation may require chemical sprays. Some markets will not accept seeds and grains treated with these chemicals.
Capital Costs	
Costs of Implementing the Technology	Costs requirements vary between storage methods. If the produce is for consumption, rather than sale, then investing large amounts in a new technology will not prove cost-efficient. On the other hand, if the amount of food for sale increases, then the investment can be paid back over time. Calculating the existing profit and potential profit with new technology is useful for businesses to estimate this payback period. The amount people are prepared to invest in new technology may depend partly upon who owns the equipment and facilities. In some cases, farmers will invest in a new technology if they have total ownership of it while in other cases, storage may be collectively owned and so costs can be shared. Access to credit is often dependent on where people live, educational levels and on being able to raise collateral. Adopting new storage methods for low-income farmers will be possible if they are given assistance with literacy and numeracy, and possibly some kind of group training.

1.8 Seed and Grain Storage	
Reduction of vulnerability to climate change, indirect	Grain storage has been established to prepare for droughts and hunger and malnutrition (UNEP, 2010). It provides an adaptation strategy for climate change by ensuring feed is available for livestock and seed stock is available in the event of poor harvests due to drought (UNEP, 2010). Efficient harvesting can reduce post-harvest losses and preserve food quantity, quality and the nutritional value of the product (FAO, 2010). Innovations for addressing climate change include technologies for reducing waste of agricultural produce (BIAC, 2009). In fact, the establishment of safe storage for seeds and reserves of food and agricultural inputs are used as indicators of adaptive capacity in the agriculture sector (CARE, 2010).
Economic Benefits	
Employment	The implementation of the technology has a good employment generation potential. This derives from training activities and construction where artisans and other labor support would required.
Investment	Relatively low capital investments are required though training and capacity building of extension agents and farmers are critical.
Public and private expenditures	Government and NGO participation and partnership is critical
Social Benefits	
Income	Good storage saves produce and enables the farmers to sell products when the market conditions are ideal rather than selling to safe the produce from post-harvest loss.
Learning	Adopting new storage methods is likely to require technical training. For example, in addition to constructing a new silo, training or advice on maintenance, health and safety regulations, quality control and seed storage behaviour (sensitivity to light and moisture) could be needed. It is important to monitor progress, in order to resolve problems, build on developments, and record successes and failures. Socio-economic impacts should be considered, such as who benefits and how additional income or time is distributed between and within households or businesses.
Health	Good storage contributes to quality of produce and protect it from spoilage which might have negative consequences on hygiene and health. Good storage contributes to nutrition.
Environmental benefits	
Good storage will reduce the use of chemicals especially in the home environment to control pests and diseases	
Local context	
Opportunities and Barriers	A common constraint is that produce has to be sold off immediately to pay off debts to landowners or creditors. This is the most widespread reason for deciding that investing in new storage technology is impossible. It has to be considered also that additional time input for constructing and maintaining storage facilities will be perceived as worthwhile only if the increase in income is sufficient.
Market Potential	The market potential for good storage services and products is high.
Status	Currently, farmers are incurring high postharvest losses due to poor storage especially from pests. Farmers stage grain in bags in the household environment with detrimental impacts on human life.
Timeframe	This technology will work in the immediate term
Acceptability to local stakeholders	Technology enjoys high acceptability rates in the communities

1.9 Selective Breeding via Controlled Mating

Technology Characteristics

Introduction	Genetic make-up influences fitness and adaptation and determines an animal's tolerance to shocks such as temperature extremes, drought, flooding, pests and diseases. Adaptation to harsh environments includes heat tolerance and an animal's ability to survive, grow and reproduce in the presence of poor seasonal nutrition as well as parasites and diseases. Selective breeding is a technology that aims to improve the value of animal genetic diversity. This technology can be applied to all types of livestock, including cattle, sheep, goats, alpacas and guinea pigs. There are three main approaches to selective breeding: **Outcrossing:** Mating two animals that are unrelated for at least 4 to 6 generations back is called an outcross. This method works best when the genetic variation for a trait is high. When dominant genes are the desirable ones, outcrossing works perfectly well. One of the best advantages of outcrossing is that it hides detrimental traits by keeping them recessive. Outcrossing improves fitness traits such as reproductive ability, milk production, kid survivability and longevity. **Linebreeding:** This involves mating related animals like half-brother/half-sister, cousins, aunt/nephew, and other more distant relationships. This is usually done to capitalise on a common outstanding ancestor who appears in recent generations of the pedigree. There is a higher degree of uniformity with linebreeding than in outcrossing, and a reduced possibility of harmful genetic defects than inbreeding. **Inbreeding**: The method involves mating directly related animals, like mother/son, father/daughter, and full brother/full sister (full siblings). This method is used generally to create uniformity and prepotency (the ability of this process to continue) and to force out latent weaknesses from the gene pool. However, recessive genes are more of a factor than dominant genes in genetic faults, so there is a high risk producing kids with problems. Inbreeding reduces the pool of available genes and can cause some lines to become extinct. Fitness traits are especially at risk with this breeding scheme.
Institutional / Organizational Requirements	Governmental institutions can provide support to selective breeding programmes by facilitating access to information and providing technical support. It will be important for MAFS to coordinate closely with communities in order to benefit from indigenous knowledge of traditional l livestock keeping. National information systems can be used to monitor threats to breeds caused by climate change or other pressures and develop predictive modelling and early warning systems. The Ministry should develop policies to strengthen livestock keepers' adaptation strategies, their ecological knowledge and local institutions. Government should provide financial incentives for breeding and raising breeds that are more resilient to climate change, promote and support marketing of products derived from these breeds, and provide infrastructure supporting selective breed production. Government institutions should also consider importing new genetic stocks with greater resistance to high temperature, for example, should the adaptative capacity of the local gene pool be limited.
Operation and maintenance	The specific advantages of selective breeding through controlled mating include low input and maintenance costs once the strategy is established, and permanence and consistency of effect. In addition, controlled mating can preserve local and rare breeds that could be lost as a result of climate change-related disease epidemics.

1.9 Selective Breeding via Controlled Mating	
Endorsement by Experts	Improvement of livestock flocks and herds through breeding has been endorsed by experts as a key strategy in Lesotho
Adequacy for Current Climate	The technology enables capacity building and adaptive capacity of farmers to prepare themselves for the uncertain but projected future scenario of low rainfall, flooding and extreme temperatures.
Size of beneficiary group	The beneficiaries include all livestock farmers in the country
Disadvantages	One of the main limitations of this technology is that selective breeding of certain genes can run the risk of reducing or removing other genes from the overall pool, a process which is irreversible. This can create new weaknesses amongst animals, particularly with the emergence of a new pest or disease. Depending on the animal traits chosen, selective breeding may not always lead to higher productivity rates.
Capital Costs	
Costs to Implement the Technology	The costs and financial requirements will depend on the livestock species and location. However, in general controlled breeding is a low-cost technology. If stones are locally available and can be used to build the mating pens, an average investment would come to around US$ 30. In areas with clay soils, adobe bricks may be used, at an average cost of US$ 90. In many cases, cattle mesh has been the chosen alternative, with an average investment of US$ 200 for each mating pen.
Reduction of vulnerability to climate change, indirect	Selective breeding through controlled mating enables farmers to breed animals that are more resistant to the impacts of climate change, such as sudden changes in temperature, prolonged droughts or the appearance of new diseases. It can reduce mortality rates, increase fertility rates, and can also be used to improve the quality of livestock products such as milk and fibre. As a result, livestock producers are at a lower risk from losing animals to climate change impacts and they are also able to diversify their income generating activities by capitalising on higher-quality dairy or fibre production.
Economic Benefits	
Employment	The technology has a high employment potential especially in technical and extension services and allied services.
Investment	Public and NGO support is critical to monitor the application of this technology in each group of animals and to review progress by examining producers' records. To apply this technology, mating pens made of adobe, stone or cattle mesh are required. Cattle mesh pens are the most expensive. Small animals can mate in wooden mating pens. Identification material such as ear tags and paint is required to monitor animals. It is also necessary to keep logbooks containing basic information on the livestock (age, gender, colour), mating data (dates, number, time), details of the offspring father, mother, colour and other basic data), animal culling, selling prices of meat, hides, dried meat, and fibre, among others.

1.9 Selective Breeding via Controlled Mating	
Public and private expenditures	The technology development process requires high level of support from government ministries and departments as well as collaboration of development partners and private sector.
Social Benefits	
Income	Good climate change adaptive livestock will stabilise and increase income of farmers.
Learning	Knowledge of current climate impacts on livestock is important for the definition of desirable traits. Where available, climate change scenarios will facilitate planning processes by providing possible future impacts on livestock animals. Livestock producers need to be trained to keep records, identify females on heat, identify key traits amongst animals, secure good quality water and feed for their livestock and build infrastructure for controlled mating. The implementing institution, or preferably the local community, must have a technician with good knowledge of the controlled mating process, capable of explaining it clearly to producers without encouraging them to reduce the number of animals they keep and recognising the need to create a nucleus of good quality livestock.
Health	Improved livestock breeds are resistant and /or tolerant of diseases and pests that are likely to come with changing climatic conditions.
Environmental benefits	
Improved livestock reaches optimum productivity and economic benefit at relatively low stock rates. In Lesotho this will reduce pressure on the rangelands and enhance recovery of environmental services.	
Local context	
Opportunities and Barriers	Despite a lack of scientifically corroborated information, indigenous knowledge about livestock genetic diversity potentially provides critical knowledge base for selective breeding. Integrating indigenous knowledge into selective breeding programmes is an opportunity for the development of low-cost, locally-appropriate strategies (Moonga and Chitambo, 2010). Documentation of the indigenous knowledge of livestock keepers about animal breeds and breeding should be an integral part of the work of rural development projects, institutions and organisations because it can be a source of information about the existence of breeds that scientists have overlooked and which may have unrecognised advantages and potential. Investments in science and technology for developing new breeds and genetic types also present an opportunity for larger-scale interventions where funding is available (IFAD, 2002). There are knowledge gaps about how breeds react to conditions brought about by climate change. The FAO (2007a; 2006) list many species and local breeds which are already adapted to high temperatures and harsh conditions, or are reported to be resistant or tolerant to various diseases. However, many of these reports are based on anecdotal evidence rather than scientific studies, and the underlying physiological and genetic mechanisms are not well understood. This makes it difficult to predict climate change impacts or develop adaptation strategies for such production systems or breeds.

1.9 Selective Breeding via Controlled Mating	
Market Potential	Livestock commodity associations in Lesotho especially the Wool and Mohair Association and Dairy Associations provide marke potential for improved livestock and technology products.
Status	The WAMPP project has invested heavilty on selective breeding in small stock in Lesotho.
Timeframe	This is an immediate to mid-term program
Acceptability to local stakeholders	The technology enjoys high acceptability rates especially among small stock (wool and mohair) and dairy farmers.

1.10 Livestock Disease Management	
Technology Characteristics	
Introduction	Livestock diseases contribute to an important set of problems within livestock production systems. These include animal welfare, productivity losses, uncertain food security, loss of income and negative impacts on human health. Livestock disease management can reduce disease through improved animal husbandry practices. These include: controlled breeding, controlling entry to farm lots, and quarantining sick animals and through developing and improving antibiotics, vaccines and diagnostic tools, evaluation of ethno-therapeutic options, and vector control techniques. Livestock disease management is made up of two key components. **Prevention (biosecurity) measures in susceptible herds:** Preventing diseases entering and spreading in livestock populations is the most efficient and cost-effective way of managing disease (Wobeser, 2002). A standard disease prevention programme that can apply in all contexts does not exist. However, the following practices aid in disease prevention: Elaboration of an animal health programme; Select a well-known, reliable source from which to purchase animals, one that can supply healthy stock, inherently vigorous and developed for a specific purpose; New animals should be monitored for disease before being introduced into the main flock; Good hygiene including clean water and feed supplies; Precise vaccination schedule for each herd or flock; Observe animals frequently for signs of disease, and if a disease problem develops, obtain an early, reliable diagnosis and apply the best treatment, control, and eradication measures for that specific disease; Dispose of all dead animals by burning, deep burying, or disposal pit; Maintain good records relative to flock or herd health including vaccination history, disease problems and medication. **Surveillance and Control Measures:** Disease surveillance allows the identification of new infections and changes to existing ones. This involves disease reporting and specimen submission by livestock owners, village veterinary staff, district and provincial veterinary officers. The method used to combat a disease outbreak depends on the severity of the outbreak. In the event of a disease outbreak the precise location of all livestock is essential for effective measures to control and eradicate contagious viruses. Restrictions on animal movements may be required as well as quarantine and, in extreme cases, slaughter.

1.10 Livestock Disease Management	
Institutional / Organizational Requirements	Lesotho cooperates with the region in programmes against trans-boundary disease through formal networks. South Africa has similar production systems and disease risk profiles and will be more likely to be affected by similar climate change impacts in livestock disease hence mutual benefits and cost savings through joint preparedness planning. This requires public policies ranging from indemnities for infected livestock to required herd depopulation and farm decontamination, to decentralisation programmes for provision of veterinary services and drug supplies. Livestock and animal health policy is oriented to both the commercial and smallholder sectors and include pro-poor interventions to support the most vulnerable populations. Government has invested in infrastructure (including early warning systems, roads, abattoirs, holding pens), systematic vaccination, as well as in research and development. Thus, providing an enabling environment for effective livestock disease management. Removing or introducing subsidies for improved management, insurance systems and supporting income diversification practices could benefit adaptation efforts (IFAD, 2009).
Operation and maintenance	The operation and maintenance of the disease management networks are the responsibility of the Government of Lesotho working together with commodity associations. Development partners are also critical support system for disease management especially FAO.
Endorsement by Experts	The disease management program is endorsed by experts locally with collaboration of regional networks.
Adequacy for Current Climate	Benefits of livestock disease prevention and control include: higher production (as morbidity is lowered and mortality or early culling is reduced), and avoided future control costs. When farmers mitigate disease through prevention or control, they benefit not just themselves but any others at risk of adverse outcomes from the presence of disease on that operation. At-risk populations include residents, visitors and consumers. The beneficiaries might also include at-risk wildlife populations surrounding the farm that may have direct or indirect contact with livestock or livestock-related material.
Size of beneficiary group	The beneficiary group includes all communities and commodity associations. However, the Government of Lesotho and South Africa have a great economic stake on the technology as well.
Disadvantages	Management options may interact, so the use of one option may diminish the effectiveness of another. Another critical issue is the long-term sustainability of currently used strategies. Chemical intervention strategies such as antibiotics or vaccines are not biologically sustainable. Animals develop resistance to drugs used to control certain viruses and with each new generation of vaccine a new and more virulent strain of the virus can arise (Tanji and Kielen, 2002). Small-scale producers may be negatively affected by livestock disease management if the full cost of the disease management programme is directly passed onto them with no subsidy from the government (FAO, 2003a)

1.10 Livestock Disease Management	
Capital Costs	
Costs for Implementation	Livestock disease management costs include: testing and screening, veterinary services, vaccines, training of livestock keepers and veterinary staff, and perhaps changes to practices and facilities to reflect movement restrictions and quarantines when animals are added to the herd. Prevention and control costs are generally evaluated against expected financial losses resulting from a disease outbreak in a cost-benefit analysis. The assumption is that increased prevention and control costs lower the expected losses by diminishing the expected scale of an infection. McInerney et al (1992) present the problem graphically as a cost minimisation problem: $\min C = L + E$ Where C is total annual disease cost, L is the value of output losses, and E is the control expenditures (which themselves are a function of inputs purchased for control).
Reduction of vulnerability to climate change, indirect	The major impacts of climate change on livestock diseases have been on diseases that are vector-borne. Increasing temperatures have supported the expansion of vector populations into cooler areas. Such cooler areas can be either higher altitude systems (for example, livestock tick-borne diseases) or more temperate zones (for example, the outbreak of bluetongue disease. Changes in rainfall pattern can also influence an expansion of vectors during wetter years and can lead to large outbreaks. Climate changes could also influence disease distribution indirectly through changes in the distribution of livestock. Improving livestock disease control is therefore an effective technology for climate change adaptation.
Economic Benefits	
Employment	Health productive livestock translates to good employment opportunities in both the technical and extension services as well as farmers.
Investment	Government and commodity association invest heavily in disease management. This includes regional and international networks and organizations.
Public and private expenditures	Public private partnerships are critical for success of the technology because the investment costs may high for farmers alone.
Social Benefits	
Income	Good disease management in livestock production begets stability in production and productivity which translates to security of income to farmers.

1.10 Livestock Disease Management

Learning

In order for producers to make decisions regarding disease management, they must understand the options open to them. These, in turn, depend on disease biology, prevention techniques, tests for infection and their costs, treatments available, market reactions, as well as industry and government programmes and policies. Disease biology includes transmission modes and rates, disease evolution (for example, length of time to infectious period), production losses associated with the disease, and mortality rate (where applicable).

Thus practical training for farmers should include: Principles of anatomy and physiology of the livestock animals; Principles of nutrition and pasture ecology Concrete Adaptation Technologies and Practices in the Agriculture Sector; Animal diseases of local importance: clinical and post mortem signs, epidemiology, prevention, treatment. Applying first aid, the use of basic veterinary medicines (wound treatments, dips, anthelmintics, antibiotics, trypanocides, babesiacides, vaccines, care and storage of medicines and vaccines, and the use and care of syringes);

Health

Modelling disease outbreaks and spread can provide valuable information for the development of management strategies. Modelling involves studying disease distribution and patterns of spread to determine the scale of a problem. This information is used to develop a model that can predict the spread of disease. Disease modelling requires prior knowledge of animal population distributions and ecology, diseases present and methods of disease transmission. Modelling can be used to assess potential disease impacts and develop contingency plans.

Environmental benefits

Disease management requires good environmental impact assessment particularly for treatment like dipping. This also applies to disposal of veterinary medical waste and implements.

Local context

Opportunities and Barriers

Where the disease organism has built up resistance against vaccines or the animal has built resistance against the disease there is an opportunity for incorporating simple, high-tech genetic approaches such as selective breeding. National planning for livestock disease management also presents an opportunity to improve agricultural support services in rural areas and to incorporate indigenous knowledge into formal prevention and control plans, thereby unlocking the potential of low-cost interventions and disseminating information on traditional lessons and experiences to a wider audience. Trans-border collaboration can provide an opportunity to strengthen veterinary services and can improve the effectiveness of disease management programmes through harmonisation of prevention and control measures, such as disease reporting and surveillance.

A lack of strong institutions and political will to monitor disease status effectively can produce a considerable barrier to livestock disease management. Difficulties in eradication of disease may also be exacerbated by many small-scale and backyard producers, infected wildlife, smuggling, and cockfighting (FAO, 2003a). If there is no compensation for stamping out disease through slaughter, then producers, particularly smallscale producers, may be reluctant to participate. If they do participate it may mean that they no longer can afford to produce (FAO, 2003a).

1.10 Livestock Disease Management	
Market Potential	Livestock community in Lesotho both households, commodity associations, NGOs, government and its development partners will find this technology useful.
Status	The Department of Livestock Services of the Ministry of Agriculture is currently anchoring this technology through technical (Veterinary and Extension Services) and financial support for purchase of veterinary drugs and providing them to farmers at subsidized prices. In addition, there is a small but strong private veterinary support service.
Timeframe	This is an immediate technology requirement
Acceptability to local stakeholders	The technology has high acceptability amongst all stakeholders (Government, Commodity Association and communities)

1.11 Sustainable Farming Systems	
Technology Characteristics	
Introduction	Farming systems are more complex than just one crop or livestock species, much of the ecological and productive resilience to climate change comes from managing a diversity of integrated production systems combining crops, livestock and trees. **Mixed farming** is an agricultural system in which a farmer conducts different agricultural practices together e.g. cash crops and livestock. The aim is to increase income through different sources and to complement land and labour demands across the year. **On-farm versus Between-farm Mixing**: On-farm mixing refers to mixing on the same farm while between-farm mixing refers to exchanging resources between different farms. The former enables the recycling of resources generated on a single farm while the latter can be used to resolve waste disposal problems e.g. use waste from animal farms for fertiliser. **Mixing within Crops and/or Animal Systems:** This practice involves multiple cropping or keeping different types of animals together. For example, grain-legume association can provide grain with nitrogen. With plant inter-cropping farmers can make the most of the space available to them by selecting plants and cropping formations that maximise the advantage of light, moisture and soil nutrients. Examples of mixed animal systems include chicken-fish production where chicken waste serves as fish fodder. **Diversified versus Integrated Systems:** In a diversified system some components exist as independent units but integrated systems maximize use of resources, making the system highly interdependent.
Institutional / Organizational Requirements	The organisations promoting this technology need to have qualified technicians both in agronomy and livestock production. These organisations must identify the farmers that are familiar with the technique of multiple crops in the area and develop positive relationships with them.

1.11 Sustainable Farming Systems	
Operation and maintenance	This technology is mainly controlled by farmers because it is basically the innovative use of existing and established technologies. Thus it is easy to operate and main once the farmer makes the decision to adopt.
Endorsement by Experts	This technology is well researched and documented for its positive effects under vulnerable situations especially in a changing climate.
Adequacy for Current Climate	This technology also allows greater food security and improved household nutrition levels. In addition, farmers can generate a surplus of some products that can be sold at market. Among other benefits, this technology also allows farmers to grow fodder for livestock and poultry. An additional benefit of mixed rice–fish culture systems is that the fish may help reduce populations of existing and emerging disease vectors such as mosquitoes.
Size of beneficiary group	The beneficiaries of the technology are mainly smallholder subsistence farmers. However, the different components are also viable for semi-commercial farmers in transition to full commercial scale which tends to favour mono-farming systems.
Disadvantages	One limitation is that production levels in mixed systems (tons ha^{-1}, milk per animal daily, increase and reproduction rates), can be lower than in specialised systems (monoculture) (FAO, 1999). Another disadvantage is that where farmers depend on wild animal stock rather than domesticated species, they may face increased vulnerability in instances where animal population levels are affected due to climate change (for example, where livestock populations need to be trimmed). Partly because of overgrazing, the mixed farming systems, in Lesotho and most of Africa, are among the most eroded and degraded systems of the world (FAO, 1996). Integrating crops and livestock can help improve soil nutrients and reduce the stress on farming land.
Capital Costs	
Costs of Implementation	As for most cases, to estimate the costs of implementing this technology the cost of wages, agricultural tools, and inputs (such as seeds and fertilisers) must be considered. Infrastructure for supporting livestock will be an added cost in crop-animal systems. The main financial needs are associated with credits for the acquisition of inputs, investment in training and in the dissemination of this technology. Investment is needed also to obtain the necessary qualitative and quantitative micro-climate information for managing the synchronisation of mixed crop cycles (phenologies).
Reduction of vulnerability to climate change, indirect	Mixed farming technology contributes to adaptation to climatic change because the diversification of crops and livestock allows farmers to have a greater number of options to face the uncertain weather conditions associated with the increased climate variability. Mixed farming can also give a more stable production because if one crop or variety fails, another may compensate. Livestock represents a means by which families can save and invest in the future. Livestock is a walking bank of assets that can be sold during periods of need such as if crops fail due to drought or flooding.
Economic Benefits	
Employment	Mixed farming systems increase opportunities for employment on farm especially where crop and livestock systems are involved.

1.11 Sustainable Farming Systems	
Investment	The levels of investment required for mixed farming systems are relatively affordable providing a good coping mechanism against the ravages of climate change.
Public and private expenditures	This technology requires only private expenditure of the farmers with public and private sector providing a conducive environment for development of requisite value chains.
Social Benefits	
Income	Small-holder farmers in Lesotho live in a climate of alternating floods and droughts. A large proportion of rural farming communities is considered to be vulnerable to severe drought. With climate change rainfall is projected to fall significantly towards 2100. In southern lowlands districts of Lesotho crop failure livestock mortality to drought are high and frequent. The average cereal production nationally is less than one ton ha^{-1}. Thus for subsistence farmers who depend only on cropping, the foregoing translates to low and unstable income per year. Hence such households, unless they have remittances or income from livestock will constitute the poorest category along with the landless. Livestock farmers especially wool and mohair growers are better off but also very vulnerable to climate change induced shocks. For these farmers, mixed farming is a viable adaptation strategy in a changing climate.
Learning	Knowledge about the phenology and lifecycles of different crops to be cultivated simultaneously (or with some time lag between them), as well as knowledge about the soil nutrients required by each of them (so they can complement each other, is required to use this technology. For example, some crops require higher levels of nitrogen, while others require more potassium. Knowledge is also required about the season in which each of the crops involved should be sown and which crop species and varieties can be grown together because of the inter-species competition.
Health	Any system that brings stability of production and income generation will ensure food security and nutrition as well as good health.
Environmental benefits	
➢ Mixed farming systems maintain soil fertility by recycling soil nutrients and allowing the introduction and use of rotations between various crops and forage legumes and trees, or for land to remain fallow and grasses and shrubs to become re-established; ➢ Mixed farming systems maintain soil biodiversity, minimise soil erosion, help to conserve water and provide suitable habitats for birds; ➢ Mixed farming systems make the best use of crop residues. When they are not used as feed, stalks may be incorporated directly into the soil, which may temporarily trap nitrogen, creating nitrogen deficiency. Burning the crop residues, the other alternative, increases carbon dioxide emissions; and ➢ Mixed farming systems allow intensified farming, with less dependence on natural resources and preserving more biodiversity than would be the case if food demands were to be met by crop and livestock activities undertaken in isolation.	

1.11 Sustainable Farming Systems

Local context

Opportunities and Barriers	The main opportunity for implementing mixed farming is that it improves and guarantees the range of products a farmer has available to sell at market. One option to increase productivity while maintaining economic and environmental benefits of mixed farming is specialisation. Partnerships with specialised farms are formed to facilitate the exchange of crops and waste products from manure. More recent developments include partnerships between dairy farmers and vegetable growers. Similarly, in organic farming between specialised organic farms there is an exchange of secondary products and crop residues for manure (FAO, 1999). The main obstacle for the implementation of this technology is farmers' reluctance since mixed farming is considered to have low productivity in comparison with monocultures which have a high yield in terms of tons per hectare. The best way to overcome these barriers is to demonstrate mixed farming systems with better productivity levels; to disseminate the benefits of this technology, and to provide training.
Market Potential	The techonogy seeks to leverage existing market potentials for the various components e.g. cereal crops, fruits and vegetables, small and large stock.
Status	The smallscale subsistence farmers in Lesotho as well as the emerging commercial farmers are largely practices different aspects of mixed farming.
Timeframe	This is an immediate term technology type
Acceptability to local stakeholders	The technology is acceptable to all farmers in Lesotho

1.12 Farmer Field Schools

Technology Characteristics

Introduction	The Farmer Field School (FFS) is a group-based learning process that has been used by a number of governments, NGOs and international agencies originally to promote integrated pest management (IPM). The first FFS were designed and managed by the Food and Agriculture Organisation (FAO) in response to perception that small farmers were not managing agrochemical-based agriculture well, particularly pest management through the use of pesticides. Many farmers did not have the resources to use pesticides, and sometimes wrong uses and storage caused the problems of poisoning. Furthermore many pests seemed to rapidly develop resistance to the pesticides. FFSs bring together concepts and methods from agroecology, experimental education and community development, as a group-based learning process. Overall, FFSs look to reinforce the understanding of farmers about the ecological processes that affect the production of their crops and animals, through conducting field learning exercises such as field observations, simple experiments and group analysis. The knowledge gained from these activities enables participants to make their own locally-specific decisions about crop management practices. Although FFSs were initiated as a training process for pest control in field crops, the principles have now been adapted to all agricultural production systems from livestock to crop production
Institutional / Organizational Requirements	The basic features of a typical FFS are as follows (Pontius et al, 2002; Bijlmakers, 2005): ➢ FFS is field-based and lasts for a full cropping season ➢ FFS meets once a week with a total number of meetings that might range from at least 10 (up to 16) meetings; ➢ The primary learning material at a FFS is the cropping field; ➢ FFS venue is close to the learning plots, often in a farmer's home and sometimes beneath a tree; ➢ FFS educational methods are experiential, participatory, and learner centred; ➢ FFS meeting includes at least three activities: ✓ The agro-ecosystem analysis, a 'special topic', and a group dynamics activity; ✓ FFS, participants conduct a study comparing plots with different managements; ✓ FFS often includes several additional field studies depending on local field problems ; ✓ Between 25 and 30 farmers participate in an FFS and learn together in small groups of five to maximise participation; ✓ FFSs include a 'field day' in which farmers make presentations the results of their studies; ✓ A pre- and post-test is conducted as part of every FFS for diagnostic purposes and for determining follow-up activities; ✓ The facilitators of FFSs undergo intensive season-long residential training to prepare them for organising and conducting FFS; ✓ Preparation meetings precede an FFS to determine needs, recruit participants, and develop a learning contract; ✓ Final meetings of the FFS often include planning for follow-up activities.

1.12 Farmer Field Schools

Operation and maintenance	Fundamental to the success of FFS is the training of the trainers of facilitators of the FFS. This often requires re-training of extension personnel in a range of skills and attitudes that were not part of their initial training. Extension personnel have typically been trained in technology transfer rather than adult education and participatory learning. FFS require facilitators to have abilities in developing understanding of the participants of agroecological processes, but not through 'lecturing' on these processes, but through facilitating the farmers in discovery exercises to find out and understand these processes. Subsequently management options are defined through the integration of local knowledge of the farmers and ecological knowledge gained through the FFS.
Endorsement by Experts	The conceptual and methodological problems associated with assessing the impact of IPM field schools have resulted in disagreements among experts about the advantages of this intervention. A World Bank has questioned the benefit of 'sending farmers back to school' (Feder et al., 2004a; Feder et al., 2004b). By contrast, a meta-analysis of 25 impact studies (van den Berg, 2004) concluded that in the majority of studies there were substantial reductions in pesticide use and in a number of cases of increased yield due to training. Furthermore the 'empowerment' impacts of the training resulted in widespread and lasting developmental impacts, such as continued learning, increased social and political skills to enable improved agro-ecosystem management.
Adequacy for Current Climate	Climate change brings many complex and unpredictable changes that affect the viability and management of farming systems. Not only are there trends in the change of temperature and rainfall, but also increased climate variability especially in the duration and intensity of the seasons. This affects a whole range of conditions relating to the performance and management of different farming systems, from planting time, to flowering, to the prevalence of different pests and diseases. To cope with this increased variability farmers will need a greater understanding of the processes that affect the performance of the different production systems they manage and undergo constant experimentation and adaptation of these production systems. More so even than the agronomic knowledge that farmers acquire from participating in FFS, the habits and abilities of constant adaptation are essential for farmers to be able to cope with climate change.
Size of beneficiary group	Smallholder farmers and households
Disadvantages	Educating farmers through FFS requires more time from both farmers and extensionists than simple technology transfer or technical recommendations. The experimentation conducted may initially generate more failures than successes, but so too have technical recommendations in the contexts of small farmer agriculture. In the medium term farmers participating in FFS leads to more sustainable impacts.

1.12 Farmer Field Schools	
Capital Costs	
Costs of Implementing Technology	The cost of conducting a season-long field school for 25 farmers has ranged from $150 to $1,000 depending on the country and the organisation (Bartlet, 2005).
Reduction of vulnerability to climate change, indirect	The FFS approach represents a radical departure from earlier agricultural extension programmes, in which farmers were expected to adopt generalised recommendations that had been formulated by specialists from outside the community. The curriculum assumes that farmers could only implement integrated crop management once they had acquired the ability to carry out their own analysis, make their own decisions and organise their own activities. The process of empowerment, rather than the adoption of specific management techniques, is what produces many of the developmental benefits of the FFS.
Economic Benefits	
Employment	The technology is a self-employment commitment on the part of the farmers
Investment	There is a significant time invest for weekly attendance of meeting. NGOs and projects often support the initiative financially for human resources and other logistics
Public and private expenditures	A public private partnership is needed to carry the support and logistical expenditures
Social Benefits	
Income	In some cases, the graduates of FFS have saved $40 per hectare per season by eliminating pesticides without any loss of yield although in other cases, graduates did not experience any savings because they were not previously using any pesticides (Bartlet, 2005). However, their yields increased by as much as 25 per cent as a result of adopting other practices learnt during the FFS, such as improved varieties, better water management and enhanced plant nutrition (Clemens et al., 2011).
Learning	Farmer field schools represent an effective mechanism for group training that can reach thousands of small-scale farmers with knowledge and technical content that each can adapt to their own unique circumstances. Beyond this, the processes empower farmers, both individually and collectively, to more effectively participate in the processes of agricultural development.
Health	The increase in production and consequent income generation translates to positive health
Environmental benefits	
FFS help farmers to cope with increased climate variability and climate change impacts on their production environment. They gain a greater understanding of the processes that affect the performance of the different production systems they manage and undergo constant experimentation and adaptation of these production systems.	

1.12 Farmer Field Schools

Local context

Opportunities and Barriers	Despite arguments among economists and policy makers, there is widespread enthusiasm for FFS among farmers and development practitioners worldwide. Participation in FFS has always been voluntary with no financial incentives provided to participants. On the contrary, participation in FFS has always involved a considerable cost in terms of time and effort. Despite these costs, two million farmers decided to participate (Clemens et al., 2011). In most countries, the demand for places in an FFS has been ahead of supply, and drop-out rates have been very low. Furthermore, there are many examples of farmers who decided to train other members of their community and continue working as a group after the training came to an end. FFS require substantial changes to the capacity of agricultural extension services, both in terms of the policies of agricultural development and the abilities of those who execute it. Re-training of agricultural extension services both represents an investment, but also resistance at all levels can be a significant impediment. Also since FFS has become a popular concept, there is the danger that the name is used for any kind of group training, but that does not really follow the concepts of building the learning capacity of the participants.
Market Potential	The concept of FFS is attractive although it will require some investment to promote it in Lesotho.
Status	There are NGOs with dedicated interest to the technology already in Lesotho. However, there is very little known or practiced in Lesotho.
Timeframe	The technology is ripe for immediate implementation going to the medium term.
Acceptability to local stakeholders	The technology is attractive theoretically but will require demonstration to farmers to enhance adoption. Pilot demonstrations are required especially with commodity associations

Annex 2 – Fact Sheets for Selected Water Sector Adaptation Technologies

2.1 Water Safety and Security Plans

Technology Characteristics

Introduction

The World Health Organization (WHO) Guidelines for Drinking Water Quality - 3rd Edition (GDWQ) (270) is the basis for current water quality standards worldwide. In the GDWQ, Water Safety Plans (WSPs) are collectively a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water. WSPs enable identification of threats to water safety during any and all steps in the catchment, transport, treatment and distribution of drinking water. This approach is fundamentally different from those traditionally adopted by water suppliers, which rely on treatment and end-product testing to ensure water safety. When implemented successfully, the WSP approach can ensure that water quality is maintained in almost any context. To introduce this technology, we outline the key components of a WSP and discuss the general steps that stakeholders must take when developing and implementing a WSP. Thus a WSP consists of three separate activities.

System assessment: potential hazards to water quality and health are identified at key steps or locations, normally referred to as Critical Control Points (CCPs), within specified boundaries of a water supply chain. Typical health hazards might be source catchment contamination, poorly maintained service reservoirs, leaking valve boxes or unhygienic standpipe collection systems (Godfrey and Howard, 2004). Associated risks of negative health outcomes due to these hazards are also quantified at this time.

Monitoring: Once health risks have been defined, they are used to develop a prioritized and system-specific plan for monitoring and controlling hazards at each CCP during the monitoring phase of a WSP. Such a plan will define operational parameters and associated sampling and reporting methods. Critical limits or targets for these parameters should be defined at this time. It is likely that a combination of observational and traditional water quality monitoring methods will be implemented by members of the community as well as by trained personnel.

Management: The actions necessary to correct any issue identified during monitoring are established in the management phase of a WSP. Such measures may include alleviation of source water contamination through controlling activities in the watershed, optimization of physical or chemical treatment processes, and prevention of recontamination during distribution, storage and handling (Water Safety Plans, 2010). By controlling hazards at the water supply system's CCPs, any issue that occurs in the catchment or distribution network can be detected and corrected before water of poor quality is delivered to the consumer. This proactive method of monitoring reduces the amount of sampling that needs to be conducted in the distribution system. In addition, processes are established for documentation and record keeping, and validation and verification during the management phase.

According to the WHO foundational document (Davidson et al., 2005), to develop a WSP, a water supplier must: i) Assemble a team that understands the water supply system and its capability to meet the water quality targets; i) Identify where contamination could arise within the water supply, and how it could be controlled; iii) Validate the methods employed to control hazards; iv) Establish both a monitoring system to check that safe water is consistently supplied and agree to corrective actions in the case of deviation outside acceptable limits; v) Periodically verify that the WSP is being implemented correctly and is achieving the performance required to meet the water safety targets.

2.1	Water Safety and Security Plans
Institutional / Organizational Requirements	The institutional and organizational requirements of a WSP are related primarily to personnel needs. The first step in planning a WSP is to set-up a steering group of multidisciplinary professionals responsible for gathering the background information required to plan a WSP and for developing its components (Godfrey and Howard, 2004). Each member must have clear terms of reference e.g. operational monitoring, documentation and reporting, monitoring results, corrective action when necessary, operational audits, certifying and validating the risk assessment plan. Stakeholder commitment and buy in are critical for successful implementation of a WSP. While representation of all stakeholder entities on the steering group will help to encourage cooperation, some cases may require additional effort from WSP designers to foster an environment of acceptance and trust. Strategies for ensuring commitment from all levels of water sector involvement have been published in the literature (Godfrey and Howard, 2004; Davidson et al., 2005).
Operation and maintenance	The implementation of a WSP will potentially require water suppliers to increase sampling frequency and number of locations where process indicators (e.g. turbidity, chlorine, residuals, pH, etc.) are monitored. However, the amount of required microbiological tests will also decrease significantly. In fact, it is likely that the cost of providing and distributing safe water from a risk-based approach will actually be less than from a traditional end-product monitoring approach (Davidson et al., 2005). This is especially true in developing countries, where consumables required for coliform and other microbiological testing are expensive and where a high percentage of monitoring funds are spent on field test kits or maintaining expensive certified laboratories. Even in cases where the equipment required for on-line monitoring must be purchased, the recurrent cost savings of using process indicators for monitoring instead of microbiological indicators is almost certain to outweigh the initial capital investment.
Endorsement by Experts	The technology has been endorsed by WHO
Adequacy for Current Climate	WSPs contribute to climate change adaptation at the catchment level primarily through increased resilience to water quality degradation. The WSP approach allows for water suppliers to be flexible and responsive to changing input parameters. This means that the monitoring, management and feedback components of a successful WSP naturally absorb the acute impacts of climate change. The WSP approach can also be modified to adapt to long-term climate change and slow-onset hazards by recognizing how the water supply system may be affected by specific climate change effects, by factoring these effects into the risk assessment, and by identifying appropriate control measures.
Size of beneficiary group	The beneficiaries are rural and urban communities throughout Lesotho
Disadvantages	Theoretically, a WSP can be put into practice at any time for a water supply of any size. In reality, small, community-managed water supply systems face a number of unique barriers to planning and implemention. In such systems, technologies may range in sophistication from a single borehole to complex treatment schemes, and operation and maintenance is performed by members of the community with limited specialist skills. In most cases, the management personnel can commit only a limited amount of time to running the system and overseeing its operation, and they receive little or no formal training or financial compensation. They are often forced to rely significantly on local or national government for general support and guidance. Furthermore, it is likely that managers of such water supply systems will have limited access to proper water quality testing and construction equipment.

2.1 Water Safety and Security Plans	
Capital Costs	
Costs of Implementation	The WSP approach can also result in long-term decreased institutional costs. In general, the planning process identifies opportunities for low-cost improvements on operations and management practices. However, WSPs also improve the efficiency of communication and collaboration between water providers, consumers, regulatory authorities and the commercial, environmental and health sectors. This creates an enabling environment where financial support can be leveraged and where capital improvement needs can be prioritized and sustained (Latin America et al., 2010).
Reduction of vulnerability to climate change, indirect	It is trite that Climate Change will lead to temperature extremes, flooding events, intense and frequent drought episodes and reduced freshwater resources (IPCC, 2007. These changes are projected to have many adverse impacts on drinking water resources such as increased: cyanobacterial activity within water bodies; frequency of physical and chemical contamination of water bodies; concentrations of harmful nutrients and pollutants in water sources;. In addition, unprotected sources will be used at increasing rates; and groundwater sources. Any hazard that occurs as a result of climate change will lead to increased health risks in the water supply chain and will have implications on water safety.
Economic Benefits	
Employment	Waterborne illnesses diminish economic productivity and confine people to poverty.
Investment	A number of stakeholders are usually involved in various aspects of the water supply chain. Therefore, the WSP design team must understand how the implementation of a WSP will affect pre-existing water sector arrangements. Understanding such arrangements will allow WSP designers to facilitate cooperation among all stakeholders. This may require a review of the current organizational and institutional structure in order to establish which entities have a vested interest in or responsibility for water safety.
Public and private expenditures	The public expenditure for setting up and ensuring sustainability of water supply systems in rural communities is the responsibility of the Department of Rural Water Supply. There is hardly any investment on WSPs. Ensuring community participation in the operation and maintenance of systems is critical but challenging. In the urban areas water supply is the jurisdiction of WASCO which imposes tarrifs on users and manage WSPs.
Social Benefits	
Income	WSPs can make a significant contribution to economic development by reducing the burden of waterborne illness in resource-limited settings.

2.1 Water Safety and Security Plans	
Learning	The WSP design team must have a sound understanding of the catchment area, treatment facilities, and distribution networks that make up a water supply system. These components must be mapped and characterized in order for the system's capability to meet water quality targets to be fully understood and for control measures to be developed. This may require in-depth assessment of the water supply chain, as some information may be unknown prior to development of the WSP. It is also important that WSP designers and stakeholders understand how water quality affects health in order for appropriate limits on specific water quality parameters to be set. This requires basic knowledge of sampling and monitoring techniques as described in the GDWQ. Furthermore, the members of the design team must have a working knowledge of the corrective actions that should be taken when water quality deviates outside acceptable limits.
Health	The burden of disease attributable to poor water, sanitation and hygiene has been estimated to be over 200 times higher in developing than in developed regions (Pruss et al., 2002). Since WSPs are developed to meet health-based targets that are specific to the disease burden of a particular region, the approach can significantly reduce the risk of exposure to health hazards that contribute the most to disease in developing countries (Davidson et al., 2005).
Environmental benefits	
A WSP helps in the monitoring of the environment	
Local context	
Opportunities and Barriers	Opportunities for WSP implementation arise whenever the supplier is motivated to pursue a risk-based approach and when the personnel capacity exists to make the necessary changes. The primary barrier to implementation of WSPs is that certain stakeholders may be hesitant to adopt such a fundamentally different paradigm for water supply management. Additionally, a number of barriers to the implementtion of WSPs that are specific to developing countries include: i) Limited data availability; ii) Unplanned development; iii) Lack of sanitation infrastructure; iv) Limited system knowledge; and v) Limited equipment/human resource availability.
Market Potential	Despite the steep adoption curve in the introduction of the WSP, the market potential is high in the urban areas.
Status	The national laboratory at WASCO and Department of Water Affairs are the custodians of the practice
Timeframe	This technology as an immediate to mid-term horizon
Acceptability to local stakeholders	The technology is highly acceptable

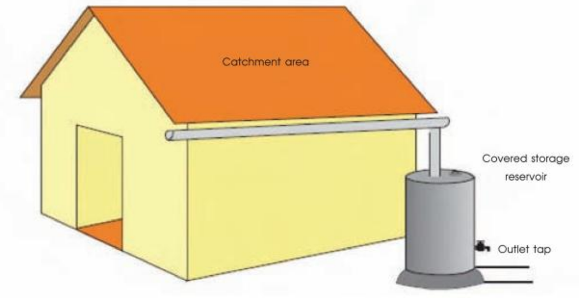
2.2 Rain Water Harvesting From Roofs

Technology Characteristics

Introduction

Collection of rainwater from rooftop catchments is an increasingly promoted technical option for supplementing household and institutional water supply. The increased proportion of hard (e.g. metal or tile) roofs and the availability of metal and plastic for conveyance have decreased the cost of implementing household rainwater harvesting (RWH). In Lesotho, RWH is used to collect water for potable and other household uses. It can also be collected for non-potable uses e.g. irrigation of landscapes (lawns and gardens), toilet flushing, and washing clothes. The range of RWH options depends on the quality, cost, and sustainability of other residential water supplies, precipitation patterns, household income, and other factors.

RWH for schools and other institutions follows the same general principles and generally benefits from economies of scale when serving large populations. Excess institutional roof water can also be used to meet residential supply. The salient features of rooftop RWH systems (Fig. 9) include: i) a catchment surface where precipitation lands; ii) a conveyance system of gutters and pipes to transport and direct the water; iii) containers to store the water for later use. Incorporating water quality protection adds one or more additional elements to system. Water quality can be protected by adding one or more of the following: filtration/screening, chemical disinfection, or a "first flush" system. First flush systems discard the initial volume of a precipitation event in order to protect water quality. It has been suggested that, as a rule of thumb, contamination is halved for each mm of rainfall discarded (234). Incorporating collected rainwater into the piped system of a residence or other building greatly increases both the expense and the expertise required.



Source: Modified from UN-HABITAT

Fig. 9. Basic features of a household RWH system (Clemens et al., 2011).

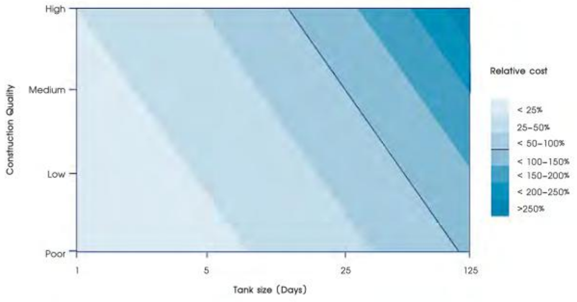
Before implementing a basic household RWH program for potable use, three questions must be answered in the affirmative (Sayana et al., 2010): i) Is current water provision thought by some householders to be seriously inadequate in quantity, cleanliness, reliability or convenience?; ii) Is there an existing capacity to specify and install RWH systems in the area, or could one be created in a suitable time?; iii) Is there adequate hard roofing area per inhabitant? This decision should be based on the planned use of rainwater (e.g. sole source of water all year, potable water only during the wet season), tank size, and average precipitation. If these three questions cannot be answered "Yes," RWH may not be suitable.

Institutional / Organizational Requirements

Basic RWH involves collection, management and use by individual households and there are few if any institutional requirements. However, storage containers usually have strong economies of scale. Therefore, groups of households can often benefit by directing rainfall to one or more large, shared storage containers. If RWH for piped dual systems is to be promoted, plumbing standards and building codes must often be modified.

<table>
<tr><th colspan="2">2.2 Rain Water Harvesting From Roofs</th></tr>
<tr><td>Operation and maintenance</td><td>Operation and maintenance consists primarily of simple cleaning and basic repairs. However, some training for households, especially related to protecting water quality (e.g. first flush methods, filtration) and budgeting rainwater are likely to lead to improved outcomes.</td></tr>
<tr><td>Endorsement by Experts</td><td>The technology is time tested and widely used worldwide with endorsement of experts and users groups.</td></tr>
<tr><td>Adequacy for Current Climate</td><td>Water is a critical factor in a changing climate. Thus with projected scenarios of drought and water scarcity optimizing use of every drop of rainfall is critical climate change adaptation strategy.</td></tr>
<tr><td>Size of beneficiary group</td><td>Both rural and urban communities and households as well as institutions especially schools, hospitals, government building</td></tr>
<tr><td>Disadvantages</td><td>Appropriate roof surfaces in rural communities could be a hindrance.</td></tr>
<tr><td colspan="2">Capital Costs</td></tr>
<tr><td>Costs of Implementation</td><td>

The relationship between cost, construction quality, and tank storage capacity is illustrated in Fig. 10. Extensive discussion of tank design, construction, and cost can be found in Thomas and Martinson (2007).



Source: Thomas and Martinson (2007).

Fig. 10. Relationship between cost, construction quality and storage capacity (Clemens et al., 2011)

In low-density rural areas, RWH can often provide household water at lower expense than other available options. If a household already has a suitable hard roof for use as a catchment surface, storage containers are the major expense. The cost of storage containers typically depends on construction quality, tank size, and other factors. A large, high quality storage container can be a major investment for poor households. In the context of climate change, increased precipitation extremes could necessitate greater storage volume, thus enabling the capture of maximum volume during intense periods and providing for household water needs during extended dry periods.

In developed countries, RWH for landscape irrigation is generally a minor investment. In contrast, dual piped systems incorporating rainwater can add significantly to the expense of a new home and retro-fitting an old home can be even more expensive.

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2.2 Rain Water Harvesting From Roofs	
Reduction of vulnerability to climate change, indirect	RWH contributes to climate change adaptation at the household level primarily through two mechanisms: i) diversification of household water supply; and ii) increased resilience to water quality degradation. It can also reduce the pressure on surface and groundwater resources (e.g. the reservoir or aquifer used for piped water supply) by decreasing household demand and has been used as a means to recharge groundwater aquifers. Another possible benefit of rooftop RWH is mitigation of flooding by capturing rooftop runoff during rainstorms. Climate change is projected to increase intensity and variability in precipitation. These are of particular concern close to the equator, where developing countries are concentrated. Storage of rainwater can provide short-term security against periods of low rainfall and the failure or degradation of other water supplies.
Economic Benefits	
Employment	Potential employment generation to artisans for construction of the system and also ofr supporting labour.
Investment	Incorporation of RWH into household water practices in developing countries can contribute significantly to development by saving money and time. Stored rainwater is a convenient, inexpensive water supply close to the home.
Public and private expenditures	This can increase the sustainability of water resources and reduce public and private expenditures associated with water infrastructure. By reducing demand for high quality water supplies and capturing water that would otherwise evaporate, RWH effectively increases per capita water availability.
Social Benefits	
Income	This can greatly decrease the time spent fetching water or queuing at water points. It can also provide significant savings for households that are sometimes forced to purchase vended or bottled water. Water scarcity can hinder economic development, human health and well-being. Therefore, in arid and semi-arid regions, even in places with a safe and reliable piped drinking water supply, RWH can contribute to development.
Learning	RWH from rooftops into storage containers has been continuously practiced in Lesotho for many years. Therefore, simple household RWH can be practiced effectively with little training or capacity building.
Health	In many settings, RWH can reduce exposure to waterborne pathogens by providing improved potable water quality and high quality water for other household purposes including hygiene, bathing and washing. In contrast to simple systems, RWH for household dual piped systems requires professional plumbers who are trained to install such systems.
Environmental benefits	
Water storage and conservation benefits have many environmental co-benefits including reduction of runoff and erosion.	

2.2 Rain Water Harvesting From Roofs	
Local context	
Opportunities and Barriers	Opportunities for investment in RWH are greatest when it can lead to time and cost savings, in addition to improved water quality and health gains. Conditions are most favorable for household RWH when other water sources are: far from the home, of degraded quality, unreliable, or expensive. When “hard” (e.g. metal or tile, in contrast to vegetative) roofing is already in use, capital costs are lower, and efficiency and water quality are superior. Barriers to implementation include inadequate or unsuitable (e.g. vegetative) roofing, lack of space for appropriate storage containers, and extreme air pollution e.g. acid rain
Market Potential	When establishing RWH in an area where it is not commonly practiced, significant capacity building is likely to be necessary. The most challenging aspects are likely to be generating sufficient demand for a self-sustaining industry and establishing supply-chains. However, most RWH hardware is not very specialized. Acceptable materials for storage and conveyance systems can be found in practically any city worldwide.
Status	The practice has been introduced and promoted by the Department of Soil Conservation with relatively low adoption rate. It has also been piloted for irrigation with much less success.
Timeframe	This technology can be used with immediate effect
Acceptability to local stakeholders	The technology is well accepted in Lesotho

2.3 Boreholes as a Drought Intervention for Domestic Water Supply

Technology Characteristics

Introduction	Increasing access to groundwater is a key strategy for household water supply (both potable and non-potable) during drought. Therefore, drought relief programs in rural areas typically incorporate drilling or deepening of boreholes. However, these activities are often inefficient and may be unnecessary (Moss, 2003). This fact sheet describes options for increasing access to groundwater during drought and provides references for pre-drought mitigation measures that reduce the need for emergency interventions. Boreholes are more specifically defined as tubewells penetrating bedrock, with casing not extending below the interface between unconsolidated soil and bedrock. They require a drilling method with an external power source. The choice of technology and drilling method depends on the cost, resources, groundwater table, desired yield and other factors. Three major strategies are employed for increasing borehole water supply during drought: a) **Drilling new boreholes/deepening existing boreholes:** These strategies form the basis of conventional approaches to improving groundwater access in rural areas during drought. They are frequently appropriate for mitigating extreme symptoms of drought although they are often not the most efficient use of limited resources (Moss, 2003). Additionally, groundwater surveys and proper siting of boreholes are necessary for achieving maximum impact; b) **Repairing damaged boreholes:** In many droughts, regional groundwater depletion is not the main factor affecting domestic access to water but when individual boreholes fail during drought, the cause is often local drawdown or mechanical failure. Studies in the region revealed that most non-functional boreholes had failed because of problems with hardware (e.g. pump failure) or demand management (e.g. localized drawdown) (Moss, 2003). The failure of a water point (including traditional sources) increases pressure on boreholes, increasing demand, local drawdown and hardware failure. Thus, repairing damaged boreholes is a quick and inexpensive way to prevent this cascade of water point failure (Carlow et al., 1997); c) **Relief boreholes with use restricted to drought periods:** Development of deep "relief boreholes" that remain capped when water supplies are adequate and are uncapped for use during drought is a strategic coping innovation (Burdon, 1985; Carlow et al., 2009). There are reports that these have been implemented successfully in Botswana (WHO and DFID, 2010). However, discontinuing access following the drought can be problematic.
Institutional / Organizational Requirements	A central groundwater database, dispite high costs, is essential to making informed decisions for groundwater access during drought (Carlow et al., 1997). Alternatively, governments can help to ensure that data from all major well-drilling entities (e.g. contractors, donors, NGOs, state enterprises) contribute to the database. Borehole logs, completion reports, test pumping data, and other useful information should be collected in a central repository for mutual benefit (Carter 2006). In addition to data on groundwater resources, having a map of existing water points and population can greatly increase drought-alleviation program efficiency and relevant methodology for water point mapping and lessons learned is available (Welle, 2005).
Operation and maintenance	The operation and maintenance of boreholes for private households is simple and straight forward. However, the challenge for Lesotho in the service of communities where logistical operations of repairs and energy costs of pumping can be daunting.
Endorsement by Experts	The technology has good endorsement by users, adaptation experts and development partners through especially in Africa and bench marked by similar situations in Asia.

2.3 Boreholes as a Drought Intervention for Domestic Water Supply	
Adequacy for Current Climate	The technology meets the technical and practical requirements for adaptation in water supply services for current and future climate projections especially for rural African situations.
Size of beneficiary group	Rural communities in Lesotho where the piped water reticulation is not operational
Disadvantages	The required capital investment for initiation is high for rural communities and requires co-investment by NGOs and /or government.
Capital Costs	
Costs of Implementation	The costs of drilling new boreholes vary widely depending many factors, hence quoting 'typical' costs can be misleading. However, the average cost in much of Africa is $10,000-15,000. In contrast, the average cost in India is less than one-tenth as much (Carter, 2006; Doyen, 2003). A detailed methodology for costing borehole drilling operations entails mobilisation/demobilisation, drilling, casing and completion, and development and test pumping (Carter et a; al., 2006). Repairing damaged wells can cost far less (sometimes by three or more orders of magnitude) than drilling new boreholes.
Reduction of vulnerability to climate change, indirect	Projected warming in Lesotho is highly likely to result in more frequent and intense drought (LMS 2018). Deep boreholes penetrating at least one impermeable layer generally have much greater resilience to drought than traditional water supplies including springs, hand dug wells and surface water sources (Gleick and Cooley, 2009). In many communities in southern lowlands of Lesotho groundwater is the only perennial source of water supply. However, a more nuanced understanding of drought is needed to formulate a proper response. Drought is defined as "a temporary aberration" in a climate pattern and is driven by variability in precipitation and evapotranspiration. This is in contrast to aridity, which is the "ordinary" climatic condition for a given area, and water stress/scarcity, which reflects renewable water resources per capita (US-NDMC, 2006; Vorosmarty et al., 2000). Drought is further divided into three categories: meteorological drought, agricultural drought, and hydrological drought. The former two are experienced earliest, but hydrological drought is the drought-type associated with shortfalls in surface water and groundwater supply (US-NMDC, 2006). Groundwater drought is sometimes used to further distinguish cases in which the water table declines and some wells dry up (Carlow et al., 1997). Many situations commonly described as drought can strongly impact rain-fed agriculture and other activities without having a direct impact on the availability of safe drinking water (Moss, 2003).
Economic Benefits	
Employment	High employment potential with private sector participation and leadership in the borehole industry
Investment	There is substantial investment capital required for effective service delivery with technical training and capacity building to avoid fly by night services.

2.3 Boreholes as a Drought Intervention for Domestic Water Supply

Public and private expenditures	The technology can safe public and private expenditures in the project future scenarios of climate change.
Social Benefits	
Income	Access to groundwater prevents reliance on poor quality alternative supplies and reduces expenditures for bottled and vended water.
Learning	Determining the best strategy for improving groundwater access during drought requires knowledge of population distribution, groundwater resources, and water point locations/status. A broad review of the factors (including capacity building) that impact the success of groundwater programs identified personnel training in the public and private well-drilling sectors (Carter, 2006).
Health	Discontinuity of water supply during drought can halt economic development and hinder human health and well-being (Gleick, 2002)
Environmental benefits	
It's important to note that the environmental benefits of boreholes depend on responsible management and sustainable practices to avoid over-extraction and contamination of groundwater sources. Additionally, the environmental impact can vary depending on local geology, hydrology, and water use practices. That notwithstanding, boreholes provide a more sustainable source of water compared to surface water during droughts and helps reduce the stress on surface water bodies. In addition, the following obtain: i) **Reduced Erosion and Habitat Preservation:** Boreholes can help reduce the need for large-scale surface water extraction, which can lead to erosion and damage to aquatic habitats. This preservation of ecosystems is vital for maintaining biodiversity; ii) **Lower Energy Consumption:** Boreholes typically require less energy for water extraction compared to pumping water from surface sources over long distances. This can result in lower greenhouse gas emissions associated with energy use; iii) **Decreased Water Transportation:** Using boreholes reduces the need for transporting water over long distances, which can help reduce fuel consumption, emissions, and the environmental impact of large-scale water transportation; iv) **Reduced Pressure on Surface Water Reservoirs:** During droughts, surface water reservoirs often experience decreased water levels. Boreholes can alleviate the pressure on these reservoirs, helping to maintain water levels for various uses, including recreation and wildlife; v) **Preservation of Wetlands:** The use of borehole technology can help preserve wetlands and other sensitive ecosystems that might be impacted by excessive surface water extraction during droughts; vii) **Groundwater Recharge:** Properly managed borehole systems can contribute to groundwater recharge during non-drought periods, replenishing aquifers and ensuring their long-term sustainability.	
Local context	

2.3	Boreholes as a Drought Intervention for Domestic Water Supply
2006Opportunities and Barriers	Proper pre-drought management can greatly increase the efficiency of these interventions and prevent costly and inefficient emergency activities. Broadly, these have been suggested to include groundwater resource assessment, groundwater drought vulnerability analysis, and building drought resistance into water supply programs (Carlow et al., 1997). Barriers for 'relief boreholes' include reported difficulties stopping access following the drought. Well-constructed deep boreholes generally yield water of good microbial quality. However, both deep and shallow aquifers can be contaminated with naturally occurring arsenic and fluoride. Although these waters can generally be used for non-potable domestic purposes, they should not be consumed without treatment. Fluoride concentrations in groundwater are generally higher at the foot of mountains. However, concentrations of these chemical species can vary widely by well location and depth, even at small geographic scales. Therefore, water testing for arsenic and fluoride should be conducted for each new well following construction and periodically during continued operation (Feentra et al., 2007; Petrusevski et al., 2006; World Bank 2005; Qian, 1999).
Market Potential	In some settings, boreholes can be sited based on available maps and observation. Sometimes expensive geophysical techniques are necessary, but the success of a method will vary widely depending on the geological environment. Borehole drilling, deepening and repair are very dependent on access to international markets for drilling equipment, spare parts and consumables. Decreasing the difficulties and costs associated with international business (e.g tariffs, import restrictions) can help to mobilize the private sector to improve groundwater access.
Status	The Department of Water Affairs has the national mandate with regulatory and administrative oversight on ground water resources. A number of private contractors has operational licensing to provide drilling services in Lesotho.
Timeframe	This is an immediate term technology horizon
Acceptability to local stakeholders	The technology has high acceptability in Lesotho especially in the rural areas

2.4 Rainwater Collection from Ground Water Surfaces, Small Reservoirs and Microcatchments

Technology Characteristics

Introduction

Most precipitation falling on human settlements is lost to the atmosphere through evapotransporation or runoff into rivers before it can be used. In regions of water scarcity small-scale collection infrastructure can contribute greatly to the volume of freshwater available for human use. This is especially true in such as the southern lowlands and Senqu river valley in Lesotho, where the little rainfall received is usually very intense and often seasonal. Because of this, runoff and river flows can be abundant for brief periods and non-existent throughout the rest of the year (Pacey and Cullis, 1986; Liebe et al., 2007). This technology entails two broad categories: i) Collecting rainfall from ground surfaces utilizing "micro-catchments" to divert or slow runoff so that it can be stored before it can evaporate or enter watercourses; and ii) Collecting flows from a river, stream or other natural watercourse i.e. floodwater harvesting by constructing an earthen or other structure to dam the watercourse and form "small reservoirs." Micro-catchments are often used to "store" water as soil moisture for agriculture. Small reservoirs are typically used in areas with seasonal rainfall to ensure that adequate water is available during the dry season. This broad categorization can provide a basic framework for defining which strategies may be appropriate in a given setting.

Collection and storage infrastructure can be natural or constructed and can take many forms including: i) Below ground tanks (i.e. cisterns) and excavations (either lined for waterproofing or unlined) into which rainwater is directed from the ground surface. Volumes of these are typically small (a few m^3 or less) and they are usually used by one household or institution (e.g. a school or health clinic; ii) Small reservoirs with earthen bunds or embankments to contain runoff or river flow. The earthen bunds or embankments are typically built from soil excavated from within the reservoir to increase storage capacity. A spillway or weir allows controlled overflow when storage capacity is exceeded; iii) Groundwater aquifers can be recharged by directing water down an unlined well. Groundwater recharge is also an added benefit of unlined reservoirs; stored water will infiltrate permeable soils during storage and eventually reach the groundwater table; iv) As soil moisture for agriculture, many runoff control methods for irrigation incorporate inundation or extended contact time with soils to increase topsoil moisture. Traditional methods were often developed in response to local conditions and have been practiced for centuries e.g. variations of contour farming to slow runoff flow, increase infiltration and decrease erosion.

Subsurface dams are another form of collection/storage infrastructure that can be used to address these same problems. Though they do not technically collect rain from the ground, they serve the same purpose as the above technologies. They have been used in Phamong (Mohal's Hoek) and Mapotu (Mafeteng) where riverbeds are often dry for a portion of the year. They consist of a low-permeability barrier (e.g. concrete) inserted into the ground across a riverbed, blocking the direction of flow. Though a seasonal riverbed may be dry at the surface, subsurface flow often continues throughout the year. Drilling a well on the upstream side of the subsurface dam enables access to water year-round. Subsurface dams cannot be applied everywhere and will only work when the stream is underlain by a shallow impermeable layer such as bedrock or clay. However, they have the advantages over conventional dams e.g. less evaporative loss, superior water quality, and less vector/parasite breeding (WHO, 2007; Foster and and Tuinof, 2004).

Groundwater is generally of superior microbial and aesthetic quality when compared to surface water. Therefore, groundwater recharge is often used to replenish aquifers that provide high quality drinking water. Rainwater collected from the ground surface is typically used for non-potable purposes, including irrigation, general domestic use, and livestock. However, in some regions with seasonal rainfall small reservoirs are commonly used for drinking water supply during the dry season, despite the high turbidity and poor bacteriological quality of the water (Cobbina et al., 2010).

2.4	Rainwater Collection from Ground Water Surfaces, Small Reservoirs and Microcatchments
Institutional / Organizational Requirements	Policies, legislation and institutional capacity are needed to address conflicts and externalities that can result from rainwater collection. Conflicts between small-scale farmers competing for limited runoff have been reported elsewhere. Additionally, as storage infrastructure grows larger it has the potential to reduce flows and negatively impact communities downstream. Small reservoir projects are likely to fail if communities do not identify the need for rainwater storage and have a choice in the technology. Management strategies of communally owned storage and irrigation infrastructure are likely to be subject to the same determinants that govern the success of small drinking water systems. The "demand-driven, community-managed" model that has worked for small drinking water supplies is likely to work for these systems as well (Whittington, 2009).
Operation and maintenance	The subsurface dams cited above are operated by two different models. In Phamong, the project is private and is operated and maintained by the Bethel vocational training center. In Mapotu, on the other hand, the dam is a community initiative donated by an FAO adaptation project and serves the community with high quality piped water. However, in the latter, the community is now operating and maintaining the system without external support. The system uses solar power to pump water from the subsurface dam into a water tank on the hill which in turn uses gravity to drive the village water supply. Thus similar models could be adopted for the other technology components.
Endorsement by Experts	Extensive guidance on rainwater and floodwater harvesting schemes for agriculture has been published by the UN Food and Agriculture Organization (FAO). Groundwater recharge using collected rainwater has recently become more widely practiced in India and elsewhere.
Adequacy for Current Climate	The scarcity of water is a major factor in a changing climate in Lesotho. Thus any practice or set of practices that address water scarcity for crops, livestock and domestic purposes is a critical and relevant adaptation need.
Size of beneficiary group	Rural communities in Lesotho with particular relevance in the southern lowlands and Senqu River Valley.
Disadvantages	Surface storage can lead to parasite/vector breeding, algal blooms and poor water quality, particularly in small reservoirs fed by agricultural runoff. Despite the poor aesthetic and microbial quality of such waters, they are often used for drinking when other water points are distant or expensive.
Capital Costs	

2.4 Rainwater Collection from Ground Water Surfaces, Small Reservoirs and Microcatchments	
Costs of Implementation	Implementation of large-scale rainwater collection programs should include a survey of current reservoir capacity and location. Satellite-based methods for tracking surface water, including radar and other methods that are not hindered by cloud cover, can reduce the costs of the survey (Liebe, 2005; Alsdorf, 2000; Alsdorf and Lettenmaier, 2003). Many factors, including the scale of the project, location, etc. will strongly affect costs. The program costs a relatively large (Brookshire, 2004) project in India costed about $50,000 (IPCC, 2007)
Reduction of vulnerability to climate change, indirect	Climate change is projected to increase the variability and intensity of rainfall in Lesotho. In many areas in Lesotho, groundwater depletion due to excessive abstraction, land use change and population growth is likely to be exacerbated by these changing precipitation patterns. Collection and storage of rainwater can provide a convenient and reliable water supply during seasonal dry periods and droughts. Additionally, widespread rainwater storage capacity can greatly reduce land erosion and flood inflow to major rivers (Liebe et al, 2005; Udawattage, 1985). Rainwater collection can also contribute greatly to the stabilization of declining groundwater tables (Stiefel, 2009; Sayana, 2010).
Economic Benefits	
Employment	The implementation of the technology entails job creation at both skilled and unskilled levels in support of construction activities.
Investment	There is a high return for investment because of the potential to enhance irrigation and aquaculture
Public and private expenditures	The improvement in water supply will potentially reduce public expenditure in health due to consumption of clean water and improvements in nutrition and food security because of improve agricultural productivity.
Social Benefits	
Income	Increased options for income generation from employment and agriculture activities.
Learning	Local governments must have the technical ability to assess these impacts if they are to prevent major externalities and resolve conflicts. Knowledge of geographic information systems (GIS) and remote sensing/satellite imagery software and other tools are necessary to determine small reservoir storage capacity (Munamati, 2010).
Health	The health co-benefits of improved water supply and agriculture productivity are high
Environmental benefits	
Rainwater collection projects can have adverse hydrological impacts on communities downstream if too much water is stored or diverted.	
Local context	

2.4	**Rainwater Collection from Ground Water Surfaces, Small Reservoirs and Microcatchments**
Opportunities and Barriers	Increased agricultural productivity, the potential for year-round water supply, and decreased time spent collecting water provide strong incentives to landowners or communities considering rainwater collection. Increased opportunities for ground-level rainwater collection should arise when rainfall is highly variable or seasonal, agricultural productivity is clearly hindered by dry periods, and alternative water supplies are distant. Barriers include the potential for adverse hydrological impacts downstream and the need for adequate capacity to assess these impacts. However, the environmental and hydrological impacts of small reservoirs have been reported to be minor (van de Giesen, 2002). Opportunities for small reservoir capacity development may arise where water availability is inadequate but environmental, social or legal concerns preclude the development of large reservoirs.
Market Potential	
Status	There is currently experience with the technology at different scales in Lesotho. These include the large commercial development of the LHDA and Lowlands. The Department of Soil Conservation also has a wealth of experience with surface water collection structures.
Timeframe	The are medium to long term projects
Acceptability to local stakeholders	The technology has high acceptability for both water supply and soil erosion control

2.5 Water Reclamation and Re-Use

Technology Characteristics

Introduction

The growth of populations and economies are causing demand for freshwater to increase. Thus, without a sound and sustainable strategy for IWRM, demand in these areas can quickly expand to exceed available supply. For this reason, there is pressure to consider municipal wastewater as a vital resource for appropriate applications e.g. agriculture, industrial and domestic uses. This practice is called water reclamation and reuse and is an example of an environmentally sound technology because it protects the environment, reduces pollution, utilizes resources more sustainably, allows its waste and products to be recycled, and handles residual wastes in a more acceptable manner than the technologies for which it substitutes (UNEP and GEC, 2004).

In this report, water reclamation is the treatment or processing of wastewater to make it reusable with definable treatment reliability and meeting appropriate water quality criteria; water reuse is the use of treated wastewater (or reclaimed water) for a beneficial purpose. The term reclaimed water is used interchangeably with recycled water hence a number of sustainable and safe approaches to meeting increasing water demand with municipal wastewater have been identified (Asano, 2007). These include: i) Substituting reclaimed water for applications that do not require potable water; ii) Augmenting existing water sources and providing an additional source of water supply to assist in meeting both present and future water needs; iii) Protecting aquatic ecosystems by decreasing the diversion of freshwater, as well as reducing the quantity of nutrients and other toxic contaminants entering waterways; iv) Postponing and reducing the need for water control structures; and v) Complying with environmental regulations by better managing water consumption and wastewater discharges

Typical wastewater treatment schemes incorporate multiple levels of physical, biological, and chemical treatment in order to ensure that water discharged to the environment does not pose a significant risk of adverse environmental or health impacts. Treated wastewater is usually discharged to surface water and that surface water is often used by a water source for a water utility downstream. Thus, many water systems reuse wastewater inadvertently. Though such unintentional reuse (also called “unplanned”, “incidental” or “natural” reuse) occurs often, it is rarely acknowledged (USEPA, 2004). Drawing attention to unintentional reuse could possibly reduce public resistance to wastewater reuse.

Water reclamation and reuse approaches utilize the same treatment technologies as conventional wastewater treatment, including secondary clarifiers, filtration basins of various designs, membranes, and disinfection basins.

Direct potable reuse is rarely recommended, regardless of the level of treatment reclaimed water has received for two reasons: i) even when it is technically feasible to remove all known contaminants from wastewater, unknown contaminants may be present; and ii) in the case of an undetected failure in the treatment process, major risks to health are likely. These two issues pose enough of a potential threat to health to render direct potable reuse impractical in most contexts. However, in most settings the main reason for not pursuing direct reuse is public opposition.

Traditionally, it has even been uncommon for drinking water reservoirs to be augmented with reclaimed water. However this practice, known as indirect potable reuse, has increased in popularity worldwide. However, for potable reuse, treatment requirements generally go beyond conventional tertiary treatment steps.

Since most urban wastewater treatment schemes and piped sewerage networks around the world are centralized, integration of reclamation and reuse approaches will likely require retrofitting of existing and construction of new infrastructure.

2.5 Water Reclamation and Re-Use	
Institutional / Organizational Requirements	The institutions that are most likely to be involved in water reclamation and reuse projects are those responsible for water supply, wastewater management, water resources management, environmental protection, public health and agriculture. Given the complexity inherent in an initiative that attempts to coordinate so many institutions at the local, regional and national levels, it may be necessary to reorganize administrative duties into a general group that coordinates reclamation and reuse projects. In addition, it would be a clear conflict of interest for either the water supplier or the wastewater manager to function as a regulatory agency that has oversight and enforcement responsibility over all the partners involved in water reuse. Therefore, it may also be necessary to task an independent agency, with such a role. A number of developing African countries have success fully made such institutional changes to facilitate water reclamation and reuse programs (USEPA, 2004).
Operation and maintenance	In general, the most economically viable applications for water reuse are those that replace potable water with reclaimed water for use in irrigation, environmental restoration, cleaning, toilet flushing, and industrial uses. These applications of reclaimed water contribute directly to conservation of water resources and pollution reduction.
Endorsement by Experts	A vast amount of information on water reclamation and reuse is available in peer-reviewed literature: textbooks (Asano et al., 2007; Jimenez and Asano, 2008), guideline documents (UNEP and GEC, 2004; USEPA, 2004), and comprehensive reviews (Okun, 2000; Andeson, 2003) have been developed in an attempt to gather and analyze this information.
Adequacy for Current Climate	The water and nutrients that can be recovered from wastewater are simply too valuable to waste in areas where resources are limited. For this reason, it is very common for farmers in developing countries to supplement their crop irrigation supplies with wastewater. In fact, except for a handful of cases where applications such as natural filtration systems for water reclamation (Takizawa, 2001), sewage reclamation for industrial uses (Kurian and Visvanathan, 2001), or direct potable reusei have been implemented, almost all water reclamation and reuse in developing countries is dedicated to agricultural irrigation. Not only does this practice increase the volume of water available for crops and utilize the nutrients in wastewater in a beneficial way, it also contributes to greater quality of human life by increasing household water availability.
Size of beneficiary group	Municipalities and urban in all 10 districts of Lesotho
Disadvantages	The planning and management approaches of 65 international nonpotable water reuse projects were documented (Mantovani et al., 2001). The survey, which covered agricultural, urban, and industrial water reuse projects in both industrialized and developing countries in arid and semi-arid areas worldwide, showed that operational performance, sound institutional arrangements, conservative cost and sales estimates, and good project communication are the basis for success in reclamation and reuse projects. Likewise, the survey also showed that institutional obstacles, inadequate valuation of economic benefits, and lack of public information can delay water reclamation and reuse projects or cause them to fail (USEPA, 2004).

2.5 Water Reclamation and Re-Use

Capital Costs

Costs of Implementation	The financial requirements for implementing water reclamation and reuse programs will vary significantly based on the type of application that is planned for the reclaimed water. Therefore, water resource managers must fully understand the costs associated with developing and managing the particular water supply, wastewater management system, and proposed water reuse system in order to compare the costs and benefits of implementing water reclamation and reuse programs with that of maintaining traditional water and wastewater management approaches. An economic analysis should be conducted in order to weigh the cost of maintaining traditional approaches and of possibly needing to develop additional water sources versus the cost of retrofitting existing and constructing new infrastructure for reuse applications. Such analyses should also consider the number of financial benefits associated with water reclamation and reuse approaches, such as reduced treatment costs and the recovery of valuable nutrients from wastewater. The life cycle cost (LCC) analysis has been used to evaluate conditions under which water reclamation and reuse programs would be cost effective (UNEP and GEC, 2004). This approach, considers the cost of the reclamation and reuse program over its entire lifespan, including design, production, installation, operations, maintenance, repair, and disposal (WHO, 2006). The analysis found that if the reclaimed water volume was more than 100 m^3 per day, the wastewater reuse option was more cost effective when compared to the conventional freshwater and sewage treatment option. Such analyses can be very helpful in determining the economic feasibility of water reclamation and reuse programs.
Reduction of vulnerability to climate change, indirect	It is now trite that Climate Change will lead to increased periods of drought, reduced freshwater stores, and sea level rise (IPCC, 2007). Such changes can have drastic impacts on both the quantity and quality of the world's water resources. However, water reclamation and reuse approaches can and have been shown to be effective for adapting water resource management in the face of such stressors. Most importantly, water reclamation and reuse, contributes to climate change adaptation by allowing water resources to be diversified and conserved. Using reclaimed water for applications that do not require potable water can result in greatly decreased depletion of protected water sources and prolong their useful lifespan. In addition, reclaimed water can be applied to permeable land surfaces or directly injected into the ground for the purpose of recharging groundwater aquifers and preventing saline intrusion in coastal areas (US EPA, 1998).

Economic Benefits

Employment	The implementation of the technology has potential for high job creation at all skills levels.
Investment	It will take a high level of investment to undertake a program of this complexity
Public and private expenditures	It will take public private partnerships to spread the expenditure levels. However, in the long term the public and private expenditure will be reduced with positive environmental co-benefits.

2.5 Water Reclamation and Re-Use

Social Benefits

Income	Job opportunities will translate to household incomes. Reducing the environmental impacts of waste will also have positive spin in saving because of good environmental health standards
Learning	Human resources: Implementation of water reclamation and reuse approaches requires the strengthening of local water and wastewater personnel's technical and managerial ability to evaluate limitations of current practice, potential benefits and requirements of wastewater reuse as well as the fostering of their capability to implement new programs.
Health	Use of untreated or unproperly treated waste water often results in high burdens of enteric disease when these crops are consumed raw or undercooked. Such diseases diminish economic productivity and confine people to poverty.

Environmental benefits

Most of the wastewater used in developing for agricultural irrigation is done so without adequate treatment (Asano et al., 2007) resulting in high burdens of enteric disease when these crops are consumed raw or undercooked. Such diseases diminish economic productivity and confine people to poverty. However, when implemented appropriately, water reclamation and reuse can contribute to social and economic development by reducing environmental pollution and enteric disease burden and increasing household water availability and crop production.

Local context

Opportunities and Barriers	Technical barriers can hinder successful implementation of water reclamation and reuse programs as well. Physical issues with transporting reclaimed water in distribution systems, such as corrosion of pipes, blockage of pipes and strainers, and biofilm formation in reservoir tanks due to reduction of residual chlorine in reclaimed water, are often cited as major concerns. In addition, implementation of reclamation and reuse programs often requires the retrofitting and construction of new and dual distribution systems as well as the development of new technologies for decentralized and satellite wastewater treatment. This can lead to prohibitively high costs that effectively limit the implementation of such programs. The issue of unknown contaminants continues to be a barrier to the implementation of potable reuse. There is a general consensus that that technology exists for rendering almost any wastewater safe for drinking by current standards, but that the uncertainties regarding trace organics and emerging contaminants impose risks, suggesting that potable reuse should be an option of last resort (Anderson, 2003; IPCC, 2007; NRC, 1998).

2.5 Water Reclamation and Re-Use	
Market Potential	Policy and regulatory framework: It will be necessary for policies and legal frameworks that facilitate safe and appropriate reclamation and reuse programs to either be created or aligned in order to ensure the protection of human health and the environment. To this effect, the following are critical: i) **Institutions:** National, regional, and local institutions will likely need to be supported in their efforts to identify ways in which they can improve effectiveness in regulating and managing water reclamation and reuse programs; ii) **Financing:** Financing opportunities and services for water reclamation and reuse initiatives will need to be expanded in order to facilitate such initiatives. It is also likely that the capability of utilities and potential users to understand and access these services will need to be improved; iii) **Participation:** Since public perception often determines the success or failure of water reclamation and reuse initiatives, civil society will need to be educated about the benefits of water reclamation and reuse as well as encouraged to participate in the decision-making process and implementation of such programs.
Status	Sewage effluents are being treated in all 10 districts of Lesotho. However, the standards of treatment and release into the environment fall far short of the kiend of requirements adduced for this technology.
Timeframe	This is a medium to long term technology
Acceptability to local stakeholders	Acceptability is good for non-potable uses of the water.

2.6 Increasing the Use of Water-Efficient Fixtures and Appliances

Technology Characteristics

Introduction

There is some evidence that per capita water use in a society follows the pattern of the Environmental Kuznets Curve (EKC) i.e. per capita water use increases rapidly with economic development to a "turning point" where it begins to decline (Yang and Jia, 2005; Anisfield, 2010). In the US, per capita water use peaked in 1975 and then declined nearly 30% over the next 30 years (Pacific Institute, 2009). Thus, while most progress in the US has been attributable to improved industrial and agricultural efficiency, the use of water efficient appliances and fixtures in homes, institutions and businesses can contribute greatly to water conservation efforts.

The most common water efficient appliances include dishwashers and clothes washing machines; popular fixtures include toilets, showerheads and faucets. They can simply use less water while yielding comparable performance (e.g. low-flow showerheads). Alternatively, these appliances can be more complex, as devices that use gray water from the sink for toilet flushing (Fig. 11). Other products give visual or audible feedback to the user about resource consumption and rely on behaviour change (Elizondo and Lofthouse, 2010).

Fig. 11. The Aqus™ toilet uses gray water from the sink for toilet flushing

The transfer of the water efficient technologies from wealthy countries to developing countries can potentially hasten progress toward the EKC "turning point" and conserve water resources (Anisfield, 2010). Making efficient appliances available on the market is necessary but may not be sufficient. Three major strategies to increase the use of water efficient appliances and fixtures are discussed below: Mandates – mandating water efficiency standards for new construction and replacement of old fixtures and appliances; mandating use of water efficient products in government facilities; Labeling – certification systems for water efficient products; adding the estimated cost of use, also called the "second price tag," to labels; Tax incentives – for purchasing and installing efficient products and /or for retro-fitting and replacing older fixtures. In addition to these, some water utilities have experimented with giving away inexpensive low-flow showerheads for free in an effort to reduce pressure on water supplies (USEPA, 2002).

Although important and effective, these are only a few of the strategies used to reduce residential water use. Educating users, metering individual homes, implementing volumetric pricing, fixing leaks, and limiting outdoor water use are also important steps for conversion (Elizondo and Lofthouse, 2010; USEPA, 2008).

2.6 Increasing the Use of Water-Efficient Fixtures and Appliances	
Institutional / Organizational Requirements	Increasing the use of water efficient appliances is primarily an institutional challenge. Although some citizens may be motivated to save water by environmental concerns, economic or other incentives are likely to be necessary to either incentivize or mandate the installation, production and sale of such appliances (Elizondo et al., 2010; Geller, 1983; Van Vugt, 2001). Transparent processes are necessary for standard-setting, testing and certification of individual products. Additionally, the use of tax incentives requires a tax structure that allows exemptions (e.g. from sales tax) or tax credits for certain purchases.
Operation and maintenance	Implementation of this technology is a collaboration between government, business and communities to create the necessary incentives and facilities.
Endorsement by Experts	This is a well documented adaptation measure and widely endorse by experts.
Adequacy for Current Climate	The technology leads to water savings with major mitigation co-benefits. Water is always is major limitation during droughts hence reducing losses and controlling excessive use is address climate change. Therefore, residential conservation efforts can make a strong positive contribution to reducing pressure on water resources. Reducing water use in municipal systems also contributes to climate change mitigation by decreasing energy consumption and greenhouse gas emissions. Water conservation can lead to large savings in the energy used to transport, treat and distribute piped water (USEPA, 2010).
Size of beneficiary group	All communities with access to piped water services which is approximately 60 percent of the Lesotho population
Disadvantage	The availability of appropriate technology might require the import of such technologies hence likelihood to increase costs. Thus their availability depends on whether the technologies are there in South Africa.
Capital Costs	
Cost of Implementation	Establishing a functioning certification process may be costly depending on existing capacity. However, the costs for individual households are generally small and may be fully recovered by water savings over the lifetime of the product.
Reduction of vulnerability to climate change, indirect	Future scenarios for Lesotho project a warmer climate and likelihood of frequent and intense drought (LMS 2018). The growing population will push the country into water stress and water scarcity between 2050 and 2100. Water conservation is an essential part of comprehensive strategies to reduce pressure on existing water resources. The industrial and agricultural sectors account for a large majority of global freshwater use. Thus, residential and agricultural water conservation efforts can make a strong positive contribution to reducing pressure on water resources. Reducing water use in municipal systems also contributes to climate change mitigation by decreasing energy consumption and greenhouse gas emissions. Water conservation can lead to large savings in the energy used to transport, treat and distribute piped water (USEPA, 2010).
Economic Benefits	

2.6 Increasing the Use of Water-Efficient Fixtures and Appliances	
Employment	There is potential employment generation in the business of technology substitution.
Investment	The indirect energy savings of water efficient fixtures (showerheads, taps and baths) are significant, reducing energy consumption for hot water heaters significantly.
Public and private expenditures	In Europe, the devices that would yield the greatest water savings if they were replaced with more water efficient products include: dishwashers (55% less water), toilets (53%), and washing machines (32%). Replacing all standard residential devices with more efficient products would result in an overall decrease of 32% (over 40,000 liters per household) (European Commission, 2009). These saving would result in reduced public and private expenditures give a positive spin in the economy by reducing production costs.
Social Benefits	
Income	Regardless of the mechanism used to encourage water conservation, policy makers and residents must be educated. Initiatives to promote water conservation may be practical in schools, through media and by other means. Branding and marketing is necessary for any certification system so that residents know the label and associate it with quality and efficiency.
Learning	A functioning infrastructure for standard-setting, testing and certification of water efficient products requires expertise across a range of areas. Professionals with experience from other sectors in standard-setting and certification may be able to transfer their knowledge to water efficiency. Alternatively, standards could be adopted in whole or part from a nearby country where the same products are generally available.
Health	Increasing access to piped water at home leads to large gains in health and development. However, domestic water demand increases rapidly as households gain access to water intensive appliances and sanitary facilities (Zhou and Tol, 2005). As population expands and water resources are stressed, economic development can be hindered (Gleick et al., 2002). Implementing residential water efficiency measures can slow the onset of water stress and preserve water resources.
Environmental benefits	
The energy saving translate to mitigation co-benefits. In addition, water saving in a changing climate where water scarcity is intense is a big environmental benefit.	
Local context	
Opportunities and Barriers	Potential for misrepresentation or corruption in a certification and labelling process is a challenge. Even countries with relatively well-functioning certification and legal systems, struggled to ensure that Energy Star labels accurately reflect energy use (170). Fixed (unmetered) water tariffs present a major barrier to implementation of residential water conservation programs as they remove any financial incentive to conserve. Populations that perceive the importance of environmental and water resource conservation will generally be more open to changing behaviours around water. In areas where people feel tightly bonded to their communities, they are more willing to set aside self-interest to conserve a common resource (169). Well-developed tax codes or the ability to exempt certain products from sales tax provide opportunities for additional incentives.

2.6 Increasing the Use of Water-Efficient Fixtures and Appliances	
Market Potential	The market potential to supply the efficient appliances is relative to the cost of the new technologies and may get a boast from government incentives. Most of the products can be imported from South Africa.
Status	Lesotho does not currently have mandatory efficiency standards for water using products
Timeframe	This is a mid-term to long term technology development for Lesotho
Acceptability to local stakeholders	The energy saving and tax incentives will boast acceptability

2.7 Leakage Management, Detection and Repair in Piped Systems

Technology Characteristics

Introduction

Non-revenue water is the difference between the volume input to a municipal distribution system (e.g. from a treatment plant) and the billed authorized consumption (e.g. water for which the utility receives payment). NRW, commonly expressed as a percentage of the total water volume input into a system, accounts for as much as 40% in some jurisdictions (Hinrichsen, 1997; McIntonsh, 2003; Farley, 2001). It consists of three categories: unbilled authorized consumption; apparent losses; and real losses. Unbilled authorized consumption (e.g. water donated to a non-profit organization) usually makes up a small fraction. Apparent losses which include unauthorized consumption (e.g. illegal connections) and meter inaccuracies often account for a considerable percentage of total NRW, especially in developing countries. Real losses consist of any water that is physically lost from the system before it reaches a consumer's water meter. A small fraction of this may include overflow of storage tanks owned by the utility. However, the vast majority of real losses are due to leakage in distribution systems. This technology fact sheet focuses on detecting and addressing this leakage.

Leakage in distribution systems is a major problem for water utilities throughout the world, in both wealthy and developing countries. Leakage rates of 10-20% are considered normal. However, in some areas, the aging infrastructure is losing up to 50% of water distributed (USEPA, 2009). In developing countries, common causes of leakage, in addition to aging pipes, include poor network design and construction, damage to exposed pipes, and leakage at poorly sealed connections (Farley, 2001).

Management, detection and repair of small leaks in a distribution system are critical functions of system operation and maintenance, yet they are often neglected. The occasional large water main breaks make sensational headlines yet they only account for about one percent of water lost to leaks (USEPA, 2009). Some small leaks are noticeable at the ground surface and are easily identified, but many leaks continue below ground for months or years. A minor leak of four liters per minute would likely continue for years before it was noticed, resulting in the loss of over two million liters per year. Leak management methods can prevent or reduce leakage volume and leak detection technology can improve the ability of water utilities to respond quickly and repair leaks (USEPA, 2009; Thomson and Wang, 2009).

Prior to implementing formal leak management, detection and repair programs, a water audit should be performed to quantify leakage and prioritize leak management activities. Water audits are typically conducted by monitoring water inputs, flow throughout the distribution system, and customer use during a low-flow period (at night); these are used to quantify losses and identify zones with high leakage. For proper leak management, information and training (Farley, 2001; Maryland Department of the Environment, 2002) and guidance (Fanner, 2008) are critical.

Metered connections are essential for water conservation and they can also serve as a leak detection mechanism for pipe beyond customer meters. Customers will usually complain to the utility when they receive an unusually high-water bill. Alternatively, an automated system to flag large increases in individual water bills or meter readings can alert utility personnel.

2.7	Leakage Management, Detection and Repair in Piped Systems
Institutional / Organizational Requirements	Institutional elements are largely governed by the perception of, and attitudes to, leakage and water waste within the water utility and political bodies (Farley, 2001). Within water utilities, an organizational climate of water conservation and financial sustainability can motivate employees to help reduce leakage. If water conservation is seen as a priority by the population, particularly under water stress or during drought, politicians who are made aware of the potential water savings may be more receptive to funding leakage management and detection programs. Leak detection and repair can be undertaken in any piped water system. However, the technologies utilized for leak detection must be appropriate to the resources of the system. For community-managed and rural systems with above-ground pipes, detection and repair of these should be prioritized. Most small utilities should generally contract leak detection to a firm with appropriate expertise.
Operation and maintenance	Effective operation and maintenance of leak detection and management technology are crucial for preventing environmental damage, ensuring safety, and minimizing economic losses. It involves regularly monitoring and managing systems designed to identify and mitigate leaks in various applications, such as pipelines, industrial facilities, or environmental monitoring. This includes: i) **System Monitoring:** Continuously monitoring sensors and equipment to detect any anomalies or deviations from normal operating conditions; ii) **Data Analysis:** Analyzing data collected from sensors to identify potential leaks or abnormalities in the system; iii) **Alert Generation:** Automatically generating alerts or notifications when a leak or issue is detected, allowing for rapid response; iv) **Regular Inspections:** Conducting routine inspections and maintenance of sensors, equipment, and software to ensure they are functioning correctly; v) **Calibration:** Periodically calibrating sensors and equipment to maintain accuracy in leak detection; vi) **System Upgrades:** Keeping technology and software up to date with the latest advancements to improve efficiency and accuracy; vii) **Emergency Response:** Developing and implementing response protocols in case of a confirmed leak, including shutting down systems, initiating containment measures, and notifying relevant authorities; viii) **Training:** Training personnel responsible for operating and maintaining the technology to ensure they are skilled in its use; ix) **Record-keeping:** Maintaining detailed records of system performance, maintenance activities, and any detected leaks for regulatory compliance and analysis; x) **Environmental Compliance:** Ensuring that the technology complies with environmental regulations and standards; **xi) Cost Management:** Managing the costs associated with technology operation and maintenance, including budgeting for replacements and upgrades as needed.
Endorsement by Experts	The WHO published a thorough training manual on leakage management and control. The content is relevant for all water utility staff, from leak inspectors to senior managers.
Adequacy for Current Climate	The adequacy of leak detection and management technology is crucial in addressing current and future climate challenges. Existing and emerging technologies play a pivotal role in mitigating greenhouse gas emissions, especially in industries like oil and gas. In summary, the adequacy of leak detection and management technology is pivotal for addressing climate change. Advancements in technology, coupled with effective policies and collaboration, are essential to meet the growing demands of a changing climate. Collaboration between governments, industries, and research institutions is crucial for developing and implementing advanced leak detection technologies. Thus, ongoing research and development efforts are essential to stay ahead of emerging climate challenges.
Size of beneficiary group	Utility companies (WASCO) and government (RWS), industry, large institutions and the urban and rural communities they serve.

2.7 Leakage Management, Detection and Repair in Piped Systems

Disadvantages

While leak detection and management technologies are crucial for efficient water resource management during droughts, they do have inherent disadvantages and limitations: i) Costly Implementation: Installing and maintaining advanced leak detection technologies can be expensive, making them less accessible for smaller municipalities with limited budgets hence cost can be deterrent to adoption of solutions; ii) False Alarms: Leak detection systems may sometimes generate false alarms, leading to unnecessary repair work and resource allocation. Such false positives can strain already limited resources during drought conditions; iii) Dependency on Infrastructure: These technologies rely on a functioning infrastructure with sensors, data networks, and personnel to operate and maintain them. In outdated or poorly developed infrastructure, implementing such systems can be challenging; iv) Limited Coverage: Leak detection systems are typically deployed in urban centers or critical infrastructure at the expense of remote or rural areas, where leaks can also occur during droughts, leaving then vulnerable; v) Energy Consumption: Some leak detection systems require continuous energy input for sensors and data transmission. Thus in areas with energy shortages or a focus on energy conservation during droughts, this can be a drawback; vi) Data Privacy and Security: Gathering and transmitting data from leak detection systems can raise concerns about data privacy and security. Safeguarding sensitive information is crucial to prevent misuse or breaches; vii) Maintenance and Expertise: These technologies require regular maintenance and trained personnel to operate effectively. In drought-affected regions with limited resources, maintaining these systems may be challenging; viii) Limited Effect on Water Supply: While leak detection helps conserve water, it may not significantly increase water supply during severe droughts. Repairing leaks may only recover a portion of the lost water, and in extreme cases, it may not alleviate water scarcity; ix) Resistance to Change: Resistance to adopting new technologies or changing traditional water management practices can be a barrier. This resistance may delay the implementation of leak detection systems; x) Environmental Impact: Some leak detection technologies, particularly those involving extensive excavation or sensor deployment, can have environmental impacts. During droughts, preserving ecosystems is crucial, and these impacts should be considered.

In conclusion, while leak detection and management technologies offer numerous benefits in drought management, they come with their own set of disadvantages and challenges. Thus implementing these technologies effectively requires careful consideration of local conditions, resources, and priorities.

Capital Costs

Costs of Implementation

The costs of leak management, detection and repair include staff training, management, labor, and equipment. However, leak management, detection and repair programs generally pay for themselves by enabling early repair of leaks and reducing water waste (Georgia EPD, 2007). Leaks often damage pipes through erosion; therefore, additional benefits of early detection include reduced maintenance costs and lower probability of catastrophic failures. Monitoring systems remotely also enables confirmation that pipes are in good condition, preventing premature replacement (Thomson and Wang, 2009).

An extensive treatment of the costs and benefits of leak management, detection and repair programs is included in the WHO training manual (Farley, 2001).

2.7 Leakage Management, Detection and Repair in Piped Systems

Reduction of vulnerability to climate change, indirect	Projected future scenarios for Lesotho indicate a warming trend with highly likelihood of more frequent and intense drought (LMS 2018) hence the growing population will push the economy into water stress and water scarcity in the mid to distal period. Thus, detection and repair of leaks in water systems is an important part of comprehensive strategies to reduce pressure on existing water resources. Reducing water use in municipal systems also contributes to climate change mitigation by decreasing greenhouse gas emissions. Detecting and preventing leakage in piped water systems can lead to large savings in the energy used to transport, treat and distribution of water (USEPA, 2010).

Economic Benefits

Employment	Leak detection and management technology can have several employment-related benefits, both directly and indirectly, by creating job opportunities and improving job quality in various sectors. In summary, leak detection and management technology contribute to employment opportunities across multiple sectors, including technology, engineering, data analysis, manufacturing, and consulting. These technologies not only help conserve resources but also stimulate job growth and the development of a skilled workforce in areas related to water management and environmental protection.

2.7	**Leakage Management, Detection and Repair in Piped Systems**
Investment	Investing in leak detection and management technology offers a range of benefits, both in terms of cost savings and environmental stewardship e.g. i) Reduced Water Loss and Costs: Leak detection technology helps identify and repair water leaks promptly, reducing non-revenue water loss. This translates into significant cost savings for water utilities, as they can sell more water without increasing production; ii) Energy Savings: Leaks in water distribution systems require extra energy to pump and treat water that is ultimately wasted. By reducing leaks, utilities can achieve substantial energy savings, lowering operational costs; iii) Extended Infrastructure Lifespan: Leak detection and timely repairs prevent the deterioration of water infrastructure. This extends the lifespan of pipelines, reducing the need for costly replacements or major repairs; iv) Improved Operational Efficiency: Leak detection technology provides real-time data and analytics, enabling utilities to optimize their operations. They can allocate resources more efficiently, respond to incidents faster, and make data-driven decisions to enhance overall efficiency; v) Compliance with Regulations: Many regions have strict regulations regarding water loss and environmental protection. Investment in leak detection technology helps utilities meet these regulatory requirements, avoiding fines and penalties; vi) Enhanced Customer Satisfaction: Conserving water resources and ensuring reliable service through leak detection measures improve customer satisfaction. Happy customers are more likely to continue using a utility's services and may even advocate for it; vii) Environmental Benefits: Leak detection reduces water waste, conserves energy, and minimizes the environmental impact of pollution incidents. This aligns with corporate sustainability goals and can enhance a company's reputation; ix) Asset Management: Leak detection systems provide valuable insights into the condition of water infrastructure. This proactive approach to asset management allows utilities and industries to plan maintenance and upgrades more effectively; x) Data-Driven Decision-Making: The data collected by leak detection systems can be leveraged for long-term planning and investment decisions. It helps utilities prioritize infrastructure improvements and allocate resources strategically; xi) Competitive Advantage: Businesses that invest in leak detection technology can gain a competitive edge by demonstrating their commitment to sustainability, efficient resource management, and environmental responsibility; xii) Resilience to Climate Change: As climate change increases the frequency and severity of droughts and extreme weather events, leak detection technology becomes an essential tool for maintaining water supply reliability and resilience. In summary, investment in leak detection and management technology delivers a wide array of financial and environmental benefits. It not only saves costs and resources but also contributes to sustainability goals and regulatory compliance, making it a wise choice for utilities, industries, and municipalities.
Public and private expenditures	Per capita demand for water increases rapidly during the development transition (Zhou and Tol, 2005). As population expands and water resources are stressed, economic development can be hindered (Gleick et al., 2002). Leakage prevention can slow the onset of water stress and preserve limited water resources. Additionally, these programs often pay for themselves through water conservation, reduced costs for treatment and distribution, and reduced maintenance and pipe replacement costs.
Social Benefits	
Income	The job employment prospects will positively influence income generation and savings
Learning	The World Health Organization (WHO) training manual for leak management and detection is an excellent capacity building tool that can enable utilities to conduct their own high-level

2.7 Leakage Management, Detection and Repair in Piped Systems

	training at low cost (Farley, 2001). Leak detection technology is developing rapidly. Large utilities should have internal expertise in the technologies best suited for monitoring their system and emerging technologies from which they may benefit.
Health	Increasing access to piped water at home leads to large gains in health and development.

Environmental benefits

Leak detection and management technology offers several significant environmental benefits, contributing to the conservation of natural resources and the reduction of environmental harm: i) Water Conservation: One of the most prominent advantages is the preservation of water resources. Leak detection systems help identify and repair leaks in water supply and distribution systems promptly, reducing water wastage. This conservation is especially critical in areas facing water scarcity and droughts; ii) Reduced Energy Consumption: Leak detection can lead to energy savings. Pumping and treating water that is lost due to leaks consumes a considerable amount of energy. By reducing these losses, energy consumption and associated greenhouse gas emissions can be minimized; iii) Lower Carbon Emissions: As leaks are repaired, the overall energy demand for water supply and treatment decreases. This reduction in energy consumption translates into lower carbon emissions, contributing to climate change mitigation efforts; iv) Preservation of Ecosystems: Leak detection helps maintain natural ecosystems by reducing the diversion of water from rivers and aquifers. This ensures that adequate water remains available to support aquatic habitats, wetlands, and wildlife during droughts and beyond; v) Protection of Water Quality: Leaks in water distribution systems can introduce contaminants or compromise water quality. Rapid leak detection and repair help safeguard the quality of drinking water, reducing the risk of pollution and its environmental impacts; vi) Prevention of Soil Erosion: Leaks in irrigation systems can lead to soil erosion as excess water saturates the ground. Leak detection in agriculture helps prevent soil erosion, preserving fertile soil and preventing sedimentation in water bodies; vii) Conservation of Energy Resources: Reducing leaks in oil and gas pipelines conserves fossil fuel resources. It also prevents potentially disastrous oil spills and gas emissions, minimizing harm to ecosystems and reducing the industry's environmental footprint; viii) Protection of Groundwater: Underground leaks can contaminate groundwater, a vital resource for drinking water and ecosystems. Leak detection prevents the migration of pollutants into aquifers, preserving groundwater quality; ix) Mitigation of Urban Flooding: In urban areas, leaks in stormwater and drainage systems can lead to flooding, which can carry pollutants into water bodies. Leak detection and repair in these systems help reduce the risk of urban flooding and associated environmental damage; x) Sustainable Resource Management: Leak detection is a key component of sustainable resource management. By efficiently using and conserving water, energy, and other resources, leak detection contributes to more responsible and eco-friendly resource utilization.

In summary, leak detection and management technology have significant environmental benefits by conserving water, reducing energy consumption and emissions, protecting ecosystems, and preventing pollution. These technologies play a crucial role in promoting sustainable and environmentally responsible resource management.

Local context

Opportunities and Barriers	Opportunities for leakage management, detection and repair programs should abound when decision-makers are made aware that the economic benefits often outweigh the costs. The economic benefits of these programs are especially great when: i) energy costs for transport, treatment and distribution are expensive; ii) infrastructure is aging and leakage is high; iii) high-profile water main breaks lead to media attention and political pressure; iv) under water stress or water scarcity conditions; and v) water conservation is valued. On the other hand, motivation to prevent leakage may be low when water is inexpensive and abundant, and when water utilities are short-staffed or under-funded.

2.7 Leakage Management, Detection and Repair in Piped Systems	
Market Potential	The market potential of leak detection and management technology is substantial and continues to grow as industries and municipalities recognize the importance of efficient resource management and environmental conservation. In conclusion, the market potential for leak detection and management technology is robust due to a convergence of factors, including regulatory pressures, technological advancements, and a heightened focus on sustainability and resource conservation. This technology is poised for continued growth and innovation in various industries and sectors globally.
Status	The technologies are currently lacking in Lesotho and unknown losses are incurred
Timeframe	The is a medium term to long term time horizon
Acceptability to local stakeholders	This has high acceptability because of the economic and environmental implications

2.8 Household Water Treatment and Safe Storage

Technology Characteristics

Introduction

Ideally, piped drinking water supplies incorporating source water protection and centralized treatment would be available to all. However, despite Lesotho boasting the status of a water tower of Southern Africa, only 60 percent of the population has access to an improved source of drinking water, and many improved sources are unsafe and some distance from the home. Despite the eventual goal of providing a safe, sustainable supply of drinking water to all people (SDG 6), the World Health Organization (WHO) and other international bodies have recognized the benefit of targeted, interim approaches for those with unsafe drinking water.

Household or point of use (POU), drinking water treatment and safe storage provides a means to improve the quality of their water by treating it in the home. Popular treatment technologies include chemical disinfectants, coagulants, ceramic filters, biological sand filters, solar disinfection (SODIS) or ultraviolet disinfection processes, and combined products with both coagulant and disinfectant (Clasen, 2009, Sobsey, 2002). These technologies have been shown to improve the microbiological and, in some cases, the chemical quality of drinking water and to reduce diarrheal disease (Sobsey, 2008; Clasen, 2006; Fewtrell, 2005). Fig. 12 shows two of the most widely promoted technologies.

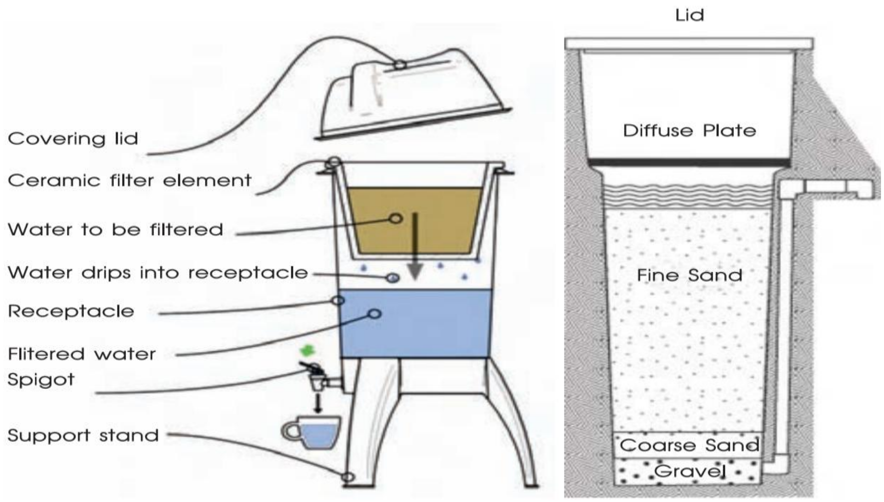

Fig. 12. Cross-sections of two popular POU filters with descriptions of the individual elements. Left: Ceramic water purifier and Right: Concrete bio-sand water filter (Clemens et al., 2011)

Household treatment of drinking water by boiling is popular and is far more widely practiced than all HWTS methods combined (Clasen, 2009). It is highly effective at eliminating all classes of pathogens. However, boiling has numerous disadvantages and has not been generally promoted by HWTS practitioners. Among these disadvantages are the time to gather fuel, the sometimes prohibitive costs, and the degradation of indoor air quality that leads to increased health hazards including respiratory infections. HWTS has become an increasingly promoted technical options in the international health community since the introduction of the Safe Water System by the US Centers for Disease Control and Prevention in 1992 (CDC Publication, No date).

2.8 Household Water Treatment and Safe Storage	
Institutional / Organizational Requirements	HWTS is a technology that is fundamentally operated and managed in the household; therefore, there are few if any institutional or organizational requirements for users. However, scaling up HWTS has proven a challenge.
Operation and maintenance	Correct and sustained use of HWTS is necessary to achieve long-term impact on user health. Although HWTS devices are generally designed to be easy to operate and maintain, the complexity of design, and the durability, operation and maintenance requirements vary. Additionally, some HWTS technologies (e.g. chemical disinfectants) are consumable and need to be replaced frequently. Although research on the factors affecting use rates of HWTS is evolving, most evidence indicates that durable technologies (e.g. filters) that do not include consumable components achieve higher rates of sustained use following implementation (Sobsey, 2008; Hunter, 2009).
Endorsement by Experts	The is accumulated scientific evidence in support of health and economic implications of the technology.
Adequacy for Current Climate	The technology is a powerful adaptation mechanism for copying with climate change induced drought and flood conditions.
Size of beneficiary group	During drought and flood conditions, the technology will benefit the community
Disadvantages	The capital costs are moderate and the technology requires some incentives especially among the rural poor.
Capital Costs	
Costs of Implementing Technology	POU disinfection was the least expensive intervention reviewed in a World Health Organization (WHO) analysis of the costs and benefits of improved water and sanitation, resulting in a benefit-to-cost ratio of between $5-and-$60 per $1 invested (Hutton and Haller, 2004). Both capital and ongoing costs must be taken into account when considering the appropriateness of an HWTS implementation program for a given community. Some technologies (e.g chemical disinfectants) have few if any capital costs but must be purchased periodically; others (e.g. biosand filters) have relatively large up-front costs with little or no on-going costs. The costs associated with training and educating users will exceed all costs associated with the HWTS "hardware." One example is solar disinfection (SODIS). In many settings, SODIS can be practiced with negligible costs, either capital or on-going. However, uptake and sustained use cannot be achieved without significant investment in training and education. Regardless of the technology, attempting to implement HWTS programs without a substantial education component is likely to decrease the long-term sustainability and impact.

2.8	**Household Water Treatment and Safe Storage**
Reduction of vulnerability to climate change, indirect	Degradation of water quality is expected to be one of the key impacts of climate change on water resources and water supply. Projected increases in flooding, drought, decreasing water availability and algal blooms have both direct and indirect effects on drinking water quality (Kundzewicz, 2007; WHO and DFID, 2010). Direct effects occur through transport of fecal and other wastes into water supplies e.g. growth of harmful algal blooms. Indirect effects on drinking water quality occur when users are forced to switch to lower quality drinking water supplies, for example when groundwater tables decline and users must switch to contaminated surface water. HWTS increases resilience to water quality degradation by enabling users to improve water quality at the point of use.
Economic Benefits	
Employment	Healthy communities will have high potential for emplyment
Investment	Households must prioritize investment in the technology to leverage the health and environmental benefits
Public and private expenditures	While the technology is on the whole a household driven initiative, government and NGO participation and collaboration will improve uptake
Social Benefits	
Income	The savings in health will translate to more disposable income to farmers
Learning	The learning curve will not be steep because communities are already familiar with the importance of boiling water during drought and flood periods. However, some incentives will go a long way to promote adoption and uptake.
Health	Diarrheal disease can be a key component of the "poverty trap" that hinders development by decreasing economic productivity (Bonds, 2009). Preventing waterborne disease can lead to increased school attendance, more time spent in gainful activities and childcare, and less diversion of limited financial resources to pay for medical care.
Environmental benefits	
During droughts or flood conditions, the environmental benefits of the technology are pronounced because pollution exerbates environmental diseases.	

2.8 Household Water Treatment and Safe Storage	
Local context	
Opportunities and Barriers	Generally, opportunities for HWTS implementation are greatest when either in the midst of a waterborne disease outbreak or when non-health benefits of HWTS are perceived to be high. HWTS does not provide the key non-health benefit of improved drinking water supply at the home, namely time-savings from not having to fetch water. However, non-health benefits include aesthetic improvement of water quality, cost savings over other water sources (e.g. bottled or vended water), and the social status associated with being able to serve treated drinking water to guests. Marketing HWTS as an “aspirational” product associated with a better lifestyle can improve uptake. Most marketing efforts of consumable HWTS products during non-crisis times have led to modest uptake and sustained use. However, recent evidence suggests that potential consumers that become aware of HWTS products through marketing campaigns will turn to those products when the perceived need is greater (e.g. during a waterborne disease outbreak).
Market Potential	Many HWTS implementation programs are donor-driven, offering partial or complete subsidization of product costs. Donor-driven HWTS programs have been successful in some settings, particularly following natural disasters and during waterborne disease outbreaks. Targeted subsidization can be used to establish products in a market. However, subsidized HWTS programs can distort the market and undermine long-term efforts to reach scale (Vousvouras and Heierli, 2010); Osborn and Holstag, 2010). Full cost recovery approaches provide the greatest potential for reaching scale. In some settings, social marketing approaches can be effective.
Status	Currently, the status of HWTS technologies in Lesotho is low and restricted to private homes who can afford health conscious habits. However, the technology is required most amongst the rural poor who don’t have access to clean water to start with.
Timeframe	The technology is an immediate to mid-term requirement especially in the rural communities of southern lowlands of Lesotho.
Acceptability to local stakeholders	The technology has high acceptability in the communities but uptake has to be incentivised.

2.9 Post-Construction Support for Community Managed Water Systems

Technology Characteristics

Introduction	In Lesotho, a large proportion of community managed water supply systems especially boreholes that were constructed with support of the Department of Rural Water Supply are dysfunctional and in a bad state of disrepair and maintenance. There is a large and growing body of evidence demonstrating that post-construction support (PCS) increases the success and sustainability of community-managed water systems including for those systems that are implemented according to all the currently recognized the best practices of the demand-driven, community-managed model (Whittington, 2009; Bakalian et al. (eds), 2009), Davis et al., 2008; WaterAid 2001; Lockwood, 2002). Rural water supply interventions have historically suffered from high rates of failure. By the 1990s a consensus developed that projects should: i) be demand-driven; ii) be managed by a community water committee; iii) require partial recovery of capital costs; iv) require full recovery of operations and maintenance costs; v) ensure the availability of spare parts for purchase through local markets; and vi) include a larger role for women in decision-making. There are demonstrated cases in Lesotho and elsewhere that applying this “demand-driven, community-managed” model to rural water projects has yielded substantial improvement in the success and sustainability of rural water supplies (Moriarty, and Schouten, 2003; Lockwood, 2002; Komives, 2009; Bartram, 1999). This success led many to the arguable assumption that, if best practices were followed during implementation, PCS would be unnecessary (Whittington, 2009; Bakalian, 2009; WaterAid 2001; Lockwood, 2002).
Institutional / Organizational Requirements	There are four basic PCS institutional models (Lockwood, 2002): a) **Centralized Model:** where support services are provided by a government agency or ministry operating from a centralized point, directly engaging with community management structures in rural areas; b) **Deconcentrated Model:** under which support services are provided by a central government agency operating, with a degree of autonomy, through regional or departmental level offices; c) **Devolution Model:** where the authority and responsibility for provision of support services is transferred from a central government agency to a decentralized tier of government, usually at the municipal level; and d) **Delegated Model:** where the responsibility for provision of support services is delegated from a central or local government agency to a third party, which could be an NGO, a private sector company or a relevant user association. Regardless of the model, it is important that the roles and responsibilities among PCS staff are defined. More crucially, perhaps, it is imperative that community water committees understand clearly which operation, maintenance and administration tasks are the responsibility of the community. The respective roles of all stakeholders should be recorded and disseminated.
Operation and maintenance	PCS can either be demand-driven (solicited) or supply driven (non-solicited). Although data are limited and newly emerging, there is some evidence that the success of these programs may depend on whether the decision to pursue PCS is initiated by the community although there are indications that large, non-solicited PCS or programs providing free repairs and free technical assistance do not lead to improved system sustainability or user-satisfaction (Whittington, 2009). This is consistent with the thinking behind the “demand-driven, community-managed” model, that requiring communities to take full responsibility for their systems will lead to improved performance. However, some non-solicited activities that help communities to renew or further develop their own capacities do show promise in improving system operation and user satisfaction. The activities that have shown greatest success in non-solicited settings include: i) non-technical financial and managerial training for committees or system operators; and ii) non-technical support visits to help water committees with administrative functions and resolution of disputes (Whittington, 2009).

2.9	Post-Construction Support for Community Managed Water Systems
	Water committees receiving non-technical PCS reportedly have a small business approach, prioritize economic sustainability and collect tariffs more frequently (Komives, 2009).
Endorsement by Experts	Access to safe and sustainable water supply, particularly water in the home, is crucial to development. However, community managed systems frequently struggle to achieve safe and sustained supply. PCS can contribute to improving performance and sustainability. Although systematic academic studies are few, extensive practical evidence indicates that PCS can improve system performance and sustainability.
Adequacy for Current Climate	Fully functional and sustainable water supply systems are prerequisite to preparation and adaptive measures to the projected climate change scenarios in which the intensity and frequency of drought is expected to lead to serious water scarcity. Therefore, the technology is suitable for both current variability and future climate change. It empowers communities to adapt appropriately to adverse rainfall conditions now in the future.
Size of beneficiary group	This technology is needed by the whole nations but most importantly in the rural communities. PCS is targeted to communities or clusters of communities and not few individuals.
Disadvantages	The benefits of PCS are primarily medium-term to long-term and are often difficult to quantify. If not demand-driven could lead to system malfunction as the critical element of ownership would be missing.
Capital Costs	
Costs of Implementation	It is crucial that PCS programs have a reliable source of funding. These costs include salaries, office overhead, training costs, and a substantial transportation budget for field staff to travel to rural communities.
Reduction of vulnerability to climate change, indirect	Approximately 60 percent of the population in Lesotho has access to piped water mostly in urban area. Increasing the resilience of the growing number of rural, community-managed piped water supplies is one of the major challenges of climate change adaptation. Community-managed water supplies are typically more vulnerable to extreme weather events and less able to assess water resource sustainability than utility-managed systems. PCS can empower community water committees and operators to access the financial, management and technical resources that enable utility-managed supplies to prepare for and adapt to adverse precipitation conditions.
Economic Benefits	
Employment	Creation of jobs to support operation and maintenance of water systems and to provide training to users /households.
Investment	Can create investments in production of items such as pump parts.

2.9 Post-Construction Support for Community Managed Water Systems

Public and private expenditures	PCS is typically carried out through government programs, municipalities, multilateral donors, and various NGOs. The technology will reduce public and private expenditures associated with completely broken down water systems.

Social Benefits

Income	Ensuring availability of water in communities would reduce household expenditure on more expensive potable water sources such as water tankers and bottled water. The water can also contribute to productive and economic livelihood purposes, especially the water system could be used for irrigation and livestock watering. The water can also contribute to productive and economic livelihood purposes, especially the water system could be used for irrigation and livestock watering.
Learning	It is important that PCS programme personnel have a broad and holistic understanding of the issues impacting the success and sustainability of rural water supplies. Historically, many practitioners have fixated on solutions within their specific area of expertise (e.g. engineers identified poor technology or construction, economists identified poor tariff structures, etc.) and were often blind to the actual problem.197 The scope of capacity building will vary widely, but training programs, manuals and, possibly, certifications may be necessary if PCS is to be implemented on a large scale. Types of PCS include, but are not limited to: i) Technical training for water system operators; ii) Technical and engineering support, including provision of technical manuals; iii) Financial and accounting assistance (e.g. setting tariffs); iv) Help settling disputes (e.g. bill payment or water sources); v) Help with maintenance, repairs and finding spare parts; vi) Help finding external funding for O&M, expansion or repairs; vii) Help assessing the sufficiency of supply for expansion or in the case of drought; viii) Household visits to residents to discuss water system use (197)
Health	Contributes to water availability and eliminates dependence of communities on unimproved water sources. Better managed systems for irrigation, for example, could result in nutritional status of beneficiary communities. These will result in improved health for households including women and children. In general, can result in stronger social cohesion in beneficiary communities.

Environmental benefits

PCS could result in water availability for the environment and protection of water bodies from proper water systems management and water conservation.

Local context

Opportunities and Barriers	The effectiveness of PCS is well-documented though not all stakeholders are aware of its importance. Incorporation of PCS into the best practices of the rural water sector, as was accomplished with the demand-driven, community-managed model, requires education of key stakeholders. PCS is sometimes viewed as a waste of resources by organizations (e.g. NGOs, donors) that prefer projects with clearer metrics of success (e.g. provided 3000 people with clean water) that are easily quantified and show rapid return on investment. Likewise, politicians prefer unveiling new projects with ribbon-cutting ceremonies. The benefits of PCS are primarily medium-term to long-term and are often difficult to quantify.

2.9 Post-Construction Support for Community Managed Water Systems	
Market Potential	The technology is small-scale, proven and less capital-intensive. It has market potential nationwide.
Status	PCS is already being undertaken in various communities in Lesotho promoted by the Department of Rural Water Supply and some NGOs. This need to be improved, strengthened and applied consistently country-wide.
Timeframe	The implementation can start now. Communities could be assisted in adapting to climate variability now while preparing for adaptation to climate change impacts in the future.
Acceptability to local stakeholders	PCS is acceptable to local stakeholders.

Annex 3 – List of Stakeholders Involved and their Contact Details

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